56852

User Manual

56852
Digitial Signal Controller

DSP56852UM
Rev. 4
06/2005

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This manual is one of a set of three documents. For complete product information, it is necessary to have all three documents. They are: 56800E Reference Manual, 56852 User Manual, and Technical Data Sheet.

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June, 2005

Summary of Changes and Updates:

Clarified SPI Chapter Section 12.9.1.5 and 12.9.2.7
Appendix C Packaging and Pin Information was removed and is now contained in the 56852 Data Sheet
Converted to Freescale format

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Preface

About This Manual

Features of the 56852 16-bit digital signal controllers (DSCs) are described in this preliminary manual release. Details of memory, operating modes, and peripheral modules are documented here. This manual is intended to be used with the *56800E Reference Manual* (56800ERM), describing the Central Processing Unit (CPU), programming models, and instruction set details. The *DSP56852 Technical Data Sheet* provides electrical specifications as well as timing, pinout, and packaging descriptions.

Audience

Information in this manual is intended to assist design and software engineers to integrate the 56852 digital signal controllers into a design and/or while developing application software.

Manual Organization

This manual is arranged in sections described here:

- **Chapter 1, 56852 Overview**—provides a brief overview, describes the structure of this document and lists other documentation necessary to use these chips.
- **Chapter 2, Pin Descriptions**—describes the 56852 pins and how the pins are grouped into various interfaces.
- **Chapter 3, Memory (MEM)**—depicts the on-chip memory, structures, registers, and interfaces.
- **Chapter 4, System Integration Module (SIM)**—documents the module responsible for system control functions.
- **Chapter 5, External Memory Interface (EMI)**—defines specifications for the IPBus-based External Memory Interface module.
- **Chapter 6, On-Chip Clock Synthesis (OCCS)**—elaborates about the internal oscillator, Phase Lock Loop (PLL), and timer distribution chain for the 56852.

- **Chapter 7, Power-On Reset (POR) and Computer Operating Properly (COP)**—narrates the on-chip Watchdog timer and the real-time interrupt generator, as well as the modes of operation.
- **Chapter 8, Interrupt Controller (ITCN)**—describes how the IPBus Interrupt Controller accepts interrupt requests from IPBus-based peripherals and presents them to the 56800E core.
- **Chapter 9, Serial Communications Interface (SCI)**—presents the Serial Communications Interface, communicating with devices such as codecs, other DSCs, microprocessors, and peripherals to provide the primary data input path.
- **Chapter 10, Serial Peripheral Interface (SPI)**—describes the Serial Peripheral Interface, the communicator with external devices, such as Liquid Crystal Displays (LCDs) and Microcontroller Units (MCUs).
- **Chapter 11, Improved Synchronous Serial Interface (ISSI)**—details the Synchronous Serial Interface, the communicator with devices such as industry-standard codecs, other DSCs, microprocessors, and peripherals to implement the Serial Peripheral Interface (SPI).
- **Chapter 12, Quad Timer (TMR)**—outlines the available internal Quad Timer devices, including features and registers.
- **Chapter 13, General Purpose Input/Output (GPIO)**—describes how peripheral pins are multiplexed with GPIO functions.
- **Chapter 14, JTAG Port**—explains the Joint Test Action Group (JTAG) testing methodology and its capabilities with Test Access Port (TAP) and Enhanced OnCE (explained in the Reference Manual).
- **Appendix A, Glossary**—provides definitions of terms, acronyms, and register names used in this manual.
- **Appendix B, Programmer's Sheets**—expands on reference tables placing all relevant data on one page; intended to be a convenient guide in programming the 56852.

Suggested Reading

A list of related books is provided here as an aid those who may be new to Digital Signal Controllers:

Advanced Topics in Signal Processing, Jae S. Lim and Alan V. Oppenheim (Prenignal tice-Hall: 1988).

Applications of Digital Signal Processing, A. V. Oppenheim (Prentice-Hall: 1978).

Digital Processing of Signals: Theory and Practice, Maurice Bellanger (John Wiley and Sons: 1984).

Digital Signal Processing, Alan V. Oppenheim and Ronald W. Schafer (Prentice-Hall: 1975).

Digital Signal Processing: A System Design Approach, David J. DeFatta, Joseph G. Lucas, and William S. Hodgkiss (John Wiley and Sons: 1988).

Discrete-Time Signal Processing, A. V. Oppenheim and R.W. Schafer (Prentice-Hall: 1989).

Foundations of Digital Signal Processing and Data Analysis, J. A. Cadzow (Macmillan: 1987).

Handbook of Digital Signal Processing, D. F. Elliott (Academic Press: 1987).

Introduction to Digital Signal Processing, John G. Proakis and Dimitris G. Manolakis (Macmillan: 1988).

IP Bus Specifications, Semiconductor Reuse Standard, SRSIPB1, v 2.0, Draft 1.6.

Multirate Digital Signal Processing, R. E. Crochiere and L. R. Rabiner (Prentice-Hall: 1983).

Signal Processing Algorithms, S. Stearns and R. Davis (Prentice-Hall: 1988).

Signal Processing Handbook, C. H. Chen (Marcel Dekker: 1988).

Signal Processing: The Modern Approach, James V. Candy (McGraw-Hill: 1988).

Theory and Application of Digital Signal Processing, Lawrence R. Rabiner and Bernard Gold (Prentice-Hall: 1975).

Manual Conventions

Conventions used in this manual:

- Bits within registers are always listed from Most Significant Bit (MSB) to Least Significant Bit (LSB).
- Bits within a register are formatted AA[n:0] when more than one bit is involved in a description. For purposes of description, the bits are presented as if they are contiguous within a register. However, this is not always the case. Refer to the programming model diagrams or to the programmer’s sheets to see the exact location of bits within a register.

- When a bit is described as *set*, its value is set to *1*. When a bit is described as *cleared*, its value is set to *0*.
- Pins or signals asserted low, made active when pulled to ground, have an overbar above their name. For example, the $\overline{SS0}$ pin is asserted low.
- Hex values are indicated with a dollar sign ($) preceding the hex value, as follows: $FFFB is the X memory address for the Interrupt Priority Register (IPR).
- Code examples follow in a single spaced font.

```
BFSET  #$0007,X:PCC ; Configure:                                  line 1

                    ; MISO0, MOSI0, SCK0 for SPI master           line 2

                    ; ~SS0 as PC3 for GPIO                        line 3
```

- Pins or signals listed in code examples asserted as low have a tilde in front of their names. In the previous example, line three refers to the $\overline{SS0}$ pin, shown as ~SS0.
- The word *reset* is used in three different contexts in this manual. The word *pin* is a generic term for any pin on the chip. They are described as:
  - a reset pin is always written as $\overline{RESET}$, in uppercase, using the over bar
  - the processor state occurs when the $\overline{RESET}$ pin is asserted. It is always written as Reset, with a capitalized first letter
  - the word *reset* refers to the reset function. It is written in lowercase, without italics, used here only for differentiation. The word may require a capital letter as style dictates, such as in headings and captions
- The word *assert* means a high true (active high) signal is pulled high to V_{DD}, or a low true (active low) signal is pulled low to ground. The word *deassert* means a high true signal is pulled low to ground, or a low true signal is pulled high to V_{DD}.

Table 0-1. Pin Conventions

Signal/Symbol	Logic State	Signal State	Voltage[1]
$\overline{\text{PIN}}$	True	Asserted	V_{IL}/V_{OL}
$\overline{\text{PIN}}$	False	Deasserted	V_{IH}/V_{OH}
PIN	True	Asserted	V_{IH}/V_{OH}
PIN	False	Deasserted	V_{IL}/V_{OL}

1.Values for VIL, VOL, VIH, and VOH are defined by individual product specifications.

Registers and tables displaying a grayed area designate reserved or unimplemented bits or registers.

= Reserved or unimplemented bit/register

The following standards are recognized in choosing block I/O signal names for the bridge:

- For clarity, all signals are referenced with capital letters throughout this document.
- Descriptive functionality of signals is taken into account when choosing signal names. This may imply names for system bus interface signals different from those defined in the 56800E specification documents.
- All efforts are made to maintain compliance with Semiconductor Reuse Standards guidelines.
- The prefix *IPBB_* is used for all signals initiated from the IPBus Bridge.
- A prefix symbolizing a specific block's name is used to distinguish input signals (point to point signals).
- All signals initiated from a particular bus will contain a prefix signifying that bus, i.e. CLK_IPB (originating from the clock).

Chapter 1
56852 Overview

1.1 Introduction

This manual describes the 56852 device. The design of the 56852 is based on the 56800E core architecture, providing more processing power than any other controller. A primary advantage of the 56852 is it can be used to support microcontroller functions ordinarily requiring a separate microcontroller. This saves designers both space and money.

The 56852 is a member of the 56800E core-based family of Digital Signal Controllers (DSCs). On a single chip, it combines the processing power of a DSP and the functionality of a microcontroller with a flexible set of peripherals to create an extremely cost-effective solution. Because of its low cost, configuration flexibility, and compact program code, the 56852 is well-suited for many applications. The chip includes many peripherals especially useful for low-end Internet appliance applications and low-end client applications such as:

- Telephony
- Portable devices
- Internet audio
- Point-of-sale systems such as noise suppression
- ID tag readers
- Sonic/subsonic detectors
- Security access devices
- Remote metering
- Sonic alarms

The 56800E core is based on a Harvard-style architecture consisting of three execution units operating in parallel, allowing as many as six operations per instruction cycle. The microprocessor-style programming model and optimized instruction set allow straightforward generation of efficient, compact code for both DSP and MCU applications. The instruction set is also highly efficient for C Compilers, enabling rapid development of optimized control applications.

The 56852 supports program execution from either internal or external memories. Two data operands can be accessed from the on-chip Data RAM per instruction cycle. The 56852 also provides two external dedicated interrupt lines, and up to 11 General Purpose Input/Output (GPIO) lines, depending on peripheral configuration.

The 56852 controller includes 6K words of Program RAM, 4K words of Data RAM and 1K of Boot ROM. This controller also provides a full set of standard programmable peripherals including one Improved Synchronous Serial Interface (ISSI), or one Serial Peripheral Interface (SPI), one improved Serial Communications Interface (SCI), and one Quad Timer (TMR). The

ISSI, SPI, SCI I/O and three chip selects can be used as General Purpose Input/Outputs (GPIOs) when its primary function is not required. The ISSI and SPI share I/O. At most, one of these two peripherals can be in use at any time.

1.2 56800E Core Description

This section provides a brief overview of the 56800E core. For a more thorough description refer to the *56800E Reference Manual (DSP56800ERM).*

1.2.1 Key Features

The 56800E architecture provides a variety of features to enhance performance, reduce application cost, and ease product development. The architectural features making these benefits possible include:

- Efficient 16-bit engine with dual Harvard architecture
- 120 Million Instructions Per Second (MIPS) at 120MHz core frequency
- Single-cycle 16 × 16-bit parallel Multiplier-Accumulator (MAC)
- Four 36-bit accumulators including extension bits
- 16-bit bidirectional shifter
- Parallel instruction set with unique addressing modes
- Hardware DO and REP loops
- Three internal address buses and one external address bus
- Four internal data buses and one external data bus
- Instruction set supports both DSP and controller functions
- Four hardware interrupt levels
- Five software interrupt levels
- Controller-style addressing modes and instructions for compact code
- Efficient C Compiler and local variable support
- Software sub routine and interrupt stack with depth limited only by memory
- JTAG/Enhanced OnCE™ debug programming interface

1.2.2 56800E Core Enhancements

The 56800E core architecture extends the 56800 family architecture. It is source-code compatible with 56800devices, adding these new features:

- Byte and long data types, supplementing the 56800’s word data type

- 24-bit data memory address space
- 21-bit program memory address space
- Two additional 24-bit pointer registers
- Two additional 36-bit accumulator registers
- Full-precision integer multiplication
- 32-bit logical and shifting operations
- Second read in dual read instruction can access off-chip memory
- Loop Count (LC) register extended to 16 bits
- Support for nested DO looping through additional loop address and count registers
- Loop address and hardware stack extended to 24 bits
- Three additional interrupt levels with a software interrupt for each level
- Enhanced On-Chip Emulation (EOnCE) with three debugging modes:
  - non-intrusive real-time debugging
  - minimally intrusive real-time debugging
  - breakpoint and step mode (core is halted)

1.2.3 System Architecture and Peripheral Interface

The 56800E system architecture encompasses all the on-chip components, including the core, on-chip memory, peripherals, and the buses necessary to connect them. **Figure 1-1** shows the overall system architecture for a device with an external bus.

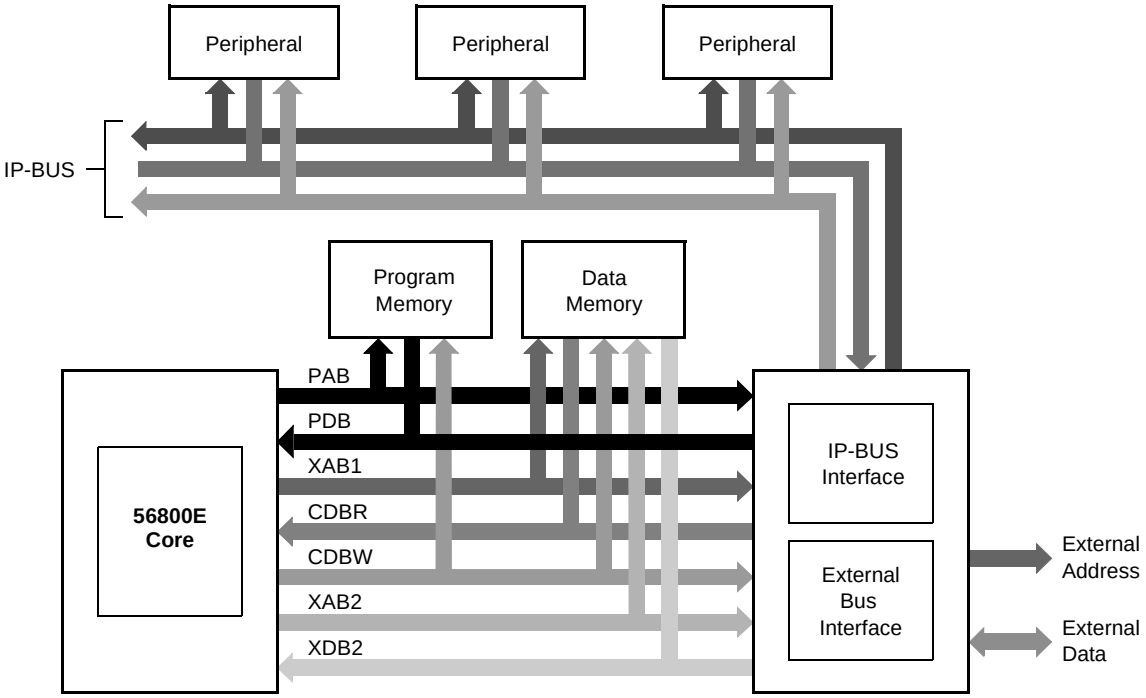


Figure 1-1. 56800E Chip Architecture with External Bus

The complete architecture includes the following components:

- 56800E core
- On-chip program memory
- On-chip data memory
- On-chip peripherals
- IPBus peripheral interface
- External bus interface

Some 56800E devices might not implement an external bus interface. Regardless of the implementation, all peripherals communicate with the 56800E core via the IPBus interface. The IPBus interface standard connects the two data address buses and the CDBR, CDBW, and XDB2 unidirectional data buses to the corresponding bus interfaces on the peripheral devices. The program memory buses are not connected to peripherals.

1.2.4 56800E Core Block Diagram

The 56800E core is composed of several independent functional units. The program controller, Address Generation Unit (AGU), and data Arithmetic Logic Unit (ALU) contain their own register sets and control logic, allowing them to operate independently and in parallel, increasing throughput. There is also an independent bit-manipulation unit, enabling efficient bit-manipulation operations. Each functional unit interfaces with the other units, memory, and the memory-mapped peripherals over the core's internal address and data buses. A block diagram of the 56800E core architecture is shown in **Figure 1-2.**

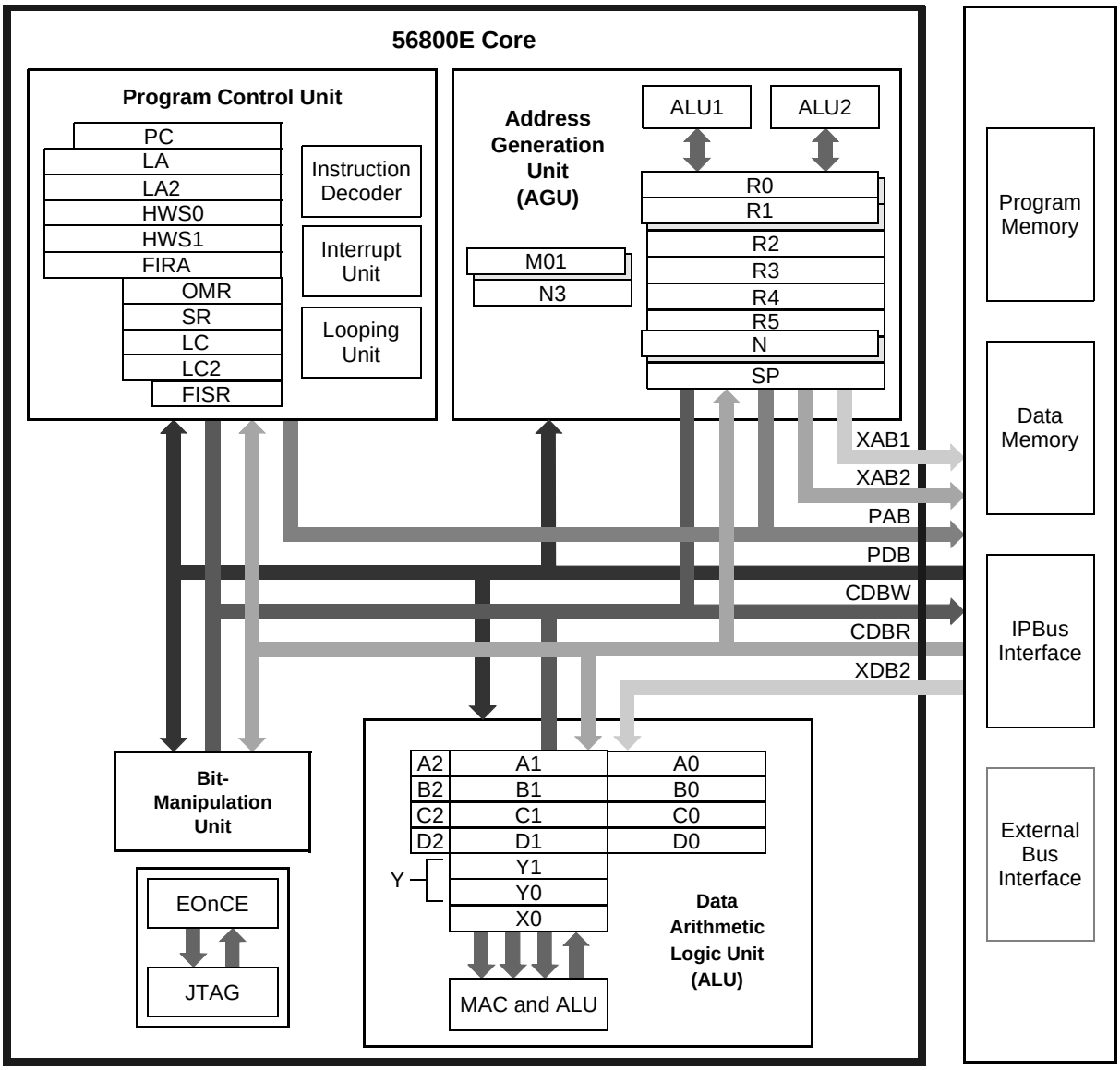


Figure 1-2. 56800E Core Block Diagram

Instruction execution is pipelined to take advantage of the parallel units, significantly decreasing the execution time for each instruction. For example, all within a single execution cycle, it is possible for the data ALU to perform a multiplication operation, for the AGU to generate up to two addresses, and for the program controller to prefetch the next instruction.

The major components of the 56800E core include:

- Address buses
- Data buses
- Data Arithmetic Logic Unit (ALU)
- Address Generation Unit (AGU)
- Program controller and hardware looping unit
- Bit-manipulation unit
- Enhanced OnCE debugging module
- Clock generation
- Reset circuitry

1.2.5 Address Buses

The core contains three address buses:

1. Program Memory Address Bus (PAB)
2. Primary Data Address Bus (XAB1)
3. Secondary Data Address Bus (XAB2)

The program address bus is 21 bits wide and is used to address (16-bit) words in program memory. The two 24-bit data address buses allow for two simultaneous accesses to data (X) memory. The XAB1 bus can address byte, word, and long data types. The XAB2 bus is limited to (16-bit) word accesses.

All three buses address on-chip memory. They can also address off-chip memory on devices containing an external bus interface unit. (The 56852 does not provide for external addressing.)

1.2.6 Data Buses

Data transfers inside the chip occur over these buses:

- Two unidirectional 32-bit buses:
  - core data bus for reads (CDBR)
  - core data bus for writes (CDBW)
- Two unidirectional 16-bit buses:
  - secondary X data bus (XDB2)
  - program data bus (PDB)
- IPBus interface

Data transfers between the data ALU and data memory use the CDBR and CDBW when a single memory read or write is performed. When two simultaneous memory reads are performed, the transfers use the CDBR and XDB2 buses. All other data transfers to core blocks occur using the CDBR and CDBW buses. Peripheral transfers occur through the IPBus interface. Instruction word fetches occur over the PDB.

This bus structure supports up to three simultaneous 16-bit transfers. Any one of the following can occur in a single clock cycle:

- One instruction fetch
- One read from data memory
- One write to data memory
- Two reads from data memory
- One instruction fetch and one read from data memory
- One instruction fetch and one write to data memory
- One instruction fetch and two reads from data memory

An instruction fetch will take place on every clock cycle, although it is possible for data memory accesses to be performed without an instruction fetch. Such accesses typically occur when a hardware loop is executed and the repeated instruction is only fetched on the first loop iteration.

1.2.7 Data Arithmetic Logic Unit (Data ALU)

The data Arithmetic Logic Unit (ALU) performs all of the arithmetic, logical, and shifting operations on data operands. The data ALU contains the following components:

- Three 16-bit data registers (X0, Y0, and Y1)
- Four 36-bit accumulator registers (A, B, C, and D)
- One multiply-accumulator (MAC) unit
- A single-bit accumulator shifter
- One arithmetic and logical multi-bit shifter
- One MAC output limiter
- One data limiter

All in a single instruction cycle, the data ALU can perform multiplication, multiply-accumulation (with positive or negative accumulation), addition, subtraction, shifting, and logical operations. Division and normalization operations are provided by iteration instructions. Signed and unsigned multiple precision arithmetic is also supported. All operations are performed using two's-complement fractional or integer arithmetic.

Data ALU source operands can be 8, 16, 32, or 36 bits in size and can be located in memory, in immediate instruction data, or in the data ALU registers. Arithmetic operations and shifts can have 16-, 32-, or 36-bit results. Logical operations are performed on 16- or 32-bit operands and yield results of the same size. The results of data ALU operations are stored either in one of the data ALU registers or directly in memory.

1.2.8 Address Generation Unit (AGU)

The Address Generation Unit (AGU) performs all of the calculations of effective addresses for data operands in memory. It contains two address ALUs, allowing up to two 24-bit addresses to be generated every instruction cycle:

- One for either the Primary Data Address Bus (XAB1) or the Program Address Bus (PAB)
- One for the Secondary Data Address Bus (XAB2)

The address ALU can perform both linear and modulo address arithmetic. The AGU operates independently of the other core units, minimizing address-calculation overhead.

The AGU can directly address 2^{24} (16M) words on the XAB1 and XAB2 buses. It can access 2^{21} (2M) words on the PAB. The XAB1 bus can address byte, word, and long data operands. The PAB and XAB2 buses can only address words in memory.

The AGU consists of the following registers and functional units:

- Seven 24-bit address registers (R0–R5 and N)
- Four 24-bit shadow registers for address registers (for R0, R1, M, and M01
- A 24-bit dedicated Stack Pointer (SP) register
- Two offset registers (N and N3)
- A 16-bit modifier register (M01)
- A 24-bit adder unit
- A 24-bit modulo arithmetic unit

Each of the address registers, R0–R5, can contain either data or an address. All of these registers can provide an address for the XAB1 and PAB address buses; addresses on the XAB2 bus are provided by the R3 register. The N offset register can be used either as a general-purpose address register or as an offset or update value for the addressing modes that support those values. The second 16-bit offset register, N3, is used only for offset or update values. The modifier register, M01, selects between linear and modulo address arithmetic.

1.2.9 Program Controller and Hardware Looping Unit

The program controller is responsible for instruction fetching and decoding, interrupt processing, hardware interlocking, and hardware looping. Actual instruction execution takes place in the other core units, such as in the data ALU, AGU, or bit-manipulation unit.

The program controller contains the following:

- An instruction latch and decoder
- The hardware looping control unit
- Interrupt control logic
- A Program Counter (PC)
- Two special registers for Fast Interrupts:
  - Fast Interrupt Return Address (FIRA) register
  - Fast Interrupt Status (FISR) register
- Seven user-accessible Status and Control registers
  - Two-level deep Hardware Stack (HWS)
  - Loop Address (LA) register
  - Loop Address 2 (LA2) register
  - Loop Count (LC) register
  - Loop Count 2 (LC2) register

— Status Register (SR)

— Operating Mode Register (OMR)

The Operating Mode Register (OMR) is a programmable register controlling the operation of the 56800E core, including the memory-map configuration. The initial operating mode is typically latched on reset from an external source; it can subsequently be altered under program control.

The Loop Address (LA) register and Loop Count (LC) register work in conjunction with the Hardware Stack (HWS) to support no-overhead hardware looping. The hardware stack is an internal Last-In-First-Out (LIFO) buffer consisting of two 24-bit words to store the address of the first instruction of a hardware DO loop. When executing the DO instruction begins a new hardware loop, the address of the first instruction in the loop is pushed onto the HWS. When a loop finishes normally or an ENDDO instruction is encountered, the value is popped from the HWS. This process allows for one hardware DO loop to be nested inside another.

1.2.10 Bit Manipulation Unit

The bit-manipulation unit performs bit field operations on data memory words, peripheral registers, and registers within the 56800E core. It is capable of testing, setting, clearing, or inverting individual or multiple bits within a 16-bit word. The bit-manipulation unit can also test bytes for branch-on-bit field instructions.

1.2.11 Programmable Chip Selects

The primary function of the Chip Selects (CS) is to provide the chip enables for external memory and peripheral devices.

There are up to four programmable chip select signals available. All chip select pins can be programmed using appropriate software.

- Reduced system complexity
- Up to four programmable active-low chip selects
- Control for external boot device
- PCS0 is assigned as both read/write program memory of size 64K upon reset ($\overline{CS}$).
- PCS1 is assigned as both read/write data memory of size 64K upon reset ($\overline{CS}$).
- Programmable base addresses with programmable block sizes
- Maximum block size = 8K (16-bit) words
- Minimum block size = 4K (16-bit) words
- Wait states programmable through the CSOR register of 56800E core, changing the number of Wait states affecting all chip selects.

- Each CS can be assigned either program memory, data memory, or both.
- All CSs are assigned for both read/write purposes.
- Each CS can be individually enabled or disabled.

1.2.12 Enhanced On-Chip Emulation (EOnCE) Module

The Enhanced On-Chip Emulation (EOnCE) module allows interaction in a debug environment with the 56800E core and its peripherals. Its capabilities include:

- Examining registers
- Accessing memory, or on-chip peripherals
- Setting breakpoints in memory
- Stepping or tracing instructions

The EOnCE module provides simple, inexpensive, and speed independent access to the 56800E core for sophisticated debugging and economical system development. The JTAG port allows access to the EOnCE module and through the 56852 device to its target system, retaining debug control without sacrificing other user accessible on-chip resources. This technique eliminates the costly cabling and access to processor pins required by traditional emulator systems. The EOnCE interface is fully described in the 56800E Reference Manual *(DSP56800ERM)*.

1.2.13 Clocks

1.2.13.1 On-Chip Clock Synthesis Block

The clock synthesis module generates the clocking for the 56852. Three different clocks are generated and used by the core and the 56852 peripherals. The clocking module contains a PLL capable of multiplying-up the frequency. Additionally, it can also be bypassed as well as being a prescaler/divider used to distribute clocks to peripherals and to lower power consumption on the 56852. There are separate power and ground for the oscillator and PLL.

1.2.13.2 Oscillators

The 56852 is clocked either from an external crystal or external clock generator input:

- Crystal oscillator uses an 2-4MHz crystal
- Ceramic resonator can be used in place of the crystal
- Oscillator output can be divided down by a programmable prescaler

1.2.13.3 PLL

Features of the PLL core provides:

- The PLL generates an interrupt to instruct the controller to gracefully shut down the system in the event the crystal is damaged or destroyed.
- The PLL continues to run for at least 100 instruction cycles if the oscillator source is removed.
- The PLL generates output frequencies up to 240MHz.
- The PLL can be bypassed to use oscillator or prescalar outputs directly.

1.2.13.4 Clock Control

A clock gear shifter guarantees smooth transition from one clock source to the next during normal operation. Clock sources available for normal operation include:

- Crystal oscillator output
- PLL output
- Programmable PLL postscaler output, a divided down version of the PLL output clock; legal divisors are 1, 2, 4, 8, 16, 32, 64, or 128.

1.3 56852 Architectural Overview

The 56852 consists of the 56800E core, program and data memory, and peripherals useful for embedded control applications. A block diagram of the 56852 is shown in **Figure 1-3.**

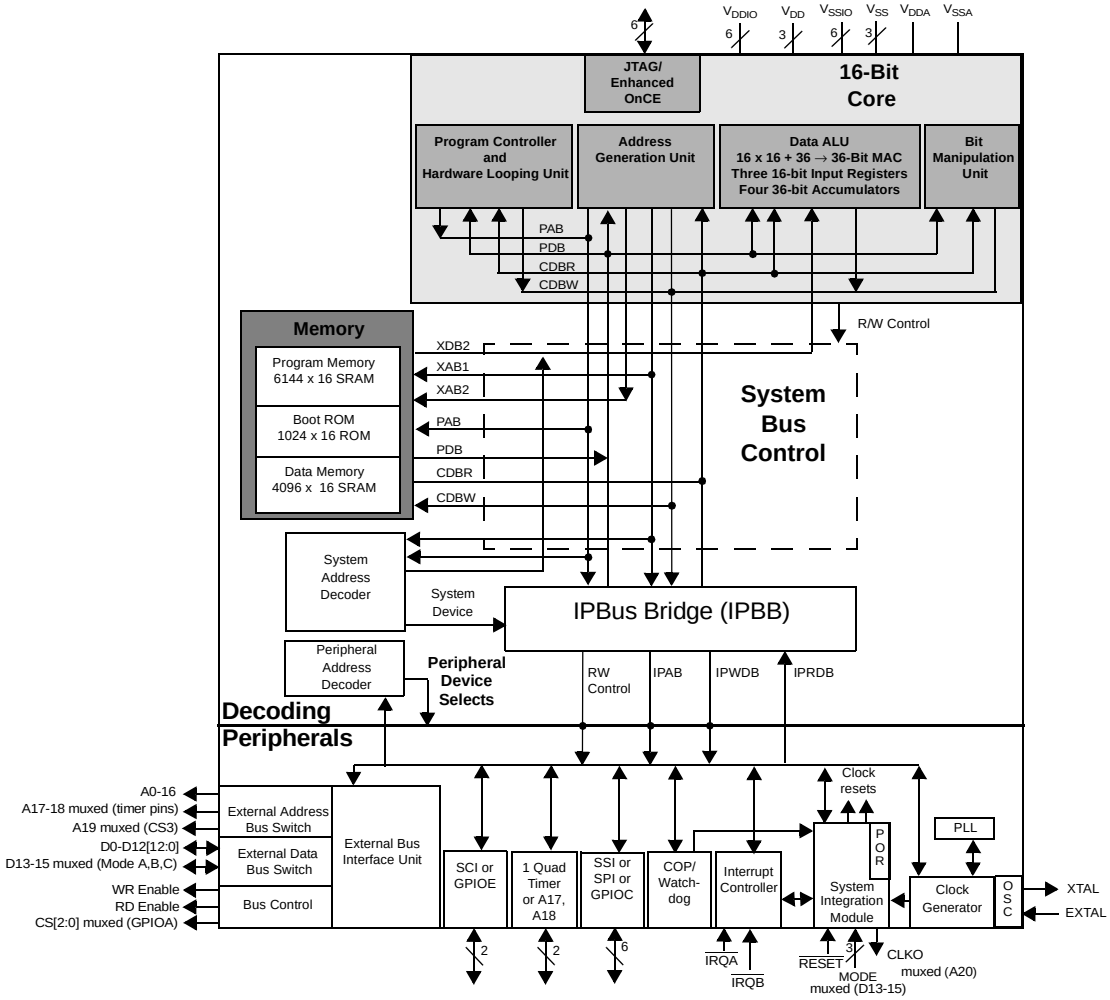


Figure 1-3. 56852 Functional Block Diagram

1.4 System Bus Controller

The 56852 System Bus Controller (SBC) provides an interface between the 56800E core and other modules on the system bus. The SBC is composed of a set of buffers for the address and

control signals originating at the core, and a separate set of multiplexers, routing data from each memory-mapped block back to the core.

The 56852 architecture includes two separate bus models:

1. System bus
2. IPBus

Internal memories and the core are located on the system buses. All peripherals and the external memory interface connect to the IPBus. Access to the IPBus by the core is facilitated by the IPBus bridge. The system bus controller does not participate in IPBus transactions. Within this document, all descriptions of bus operations pertain only to the system bus.

For performance reasons, all system bus signals in the 56852 architecture have a single driver, as opposed to the more common three-state bus configurations. Read data from each memory-mapped device is multiplexed to avoid contention. Since the core is the only system bus master, there is no need for multiplexers on the address, control or write data buses.

1.4.1 Operation Method

The 56800E system utilizes a pipelined memory architecture and separate program and X data buses. Each memory cycle is completed in three or more system clock cycles. During the first of these cycles, the core presents an address, along with control signals, to indicate the type of memory cycle being initiated. This clock cycle is referred to as the address phase of a memory cycle. The following cycle is an intermediate step not involving bus activity related to the memory cycle in progress. Finally, the data phase occurs. During this phase data is transferred to or from the master, depending upon the type of cycle initiated during the address phase.

Memory cycles can overlap in each clock cycle, a new address phase can begin while the data phase for a preceding memory cycle occurs. In certain cases, memory devices or the core may require additional time to complete operations. When this occurs, clock edges to other modules are withheld by the clock generation circuitry. This activity is transparent to the operation of the SBC.

1.4.2 IPBus Bridge (IPBB)

The IPBus Bridge (IPPB) provides a means for communication between the high speed core and the low-bandwidth devices on the IP peripheral bus. Among other functions, the bridge is

responsible for maintaining an orderly and synchronized communication between devices on both sides running at two different clock frequencies.

The IPBus architecture supports a variety of on-chip peripherals. Among those peripherals available are:

- Phase-Locked Loop (PLL) module
- 16-bit Quad Timer (TMR) module
- Computer Operating Properly (COP) module
- Improved Synchronous Serial Interface (ISSI) module
- Serial Peripheral Interface (SPI) module
- Serial Communication Interface (SCI/UART) module
- Programmable General-Purpose I/O (GPIO) module

Figure 1-1 denotes the position and interface of the IPBus Bridge with other main blocks within the chip.

Other connections in the figure not pertaining to the primary function of the bridge are omitted for clarity; nevertheless, they will be discussed as appropriate. A brief description of bridge's interface with various main components on both sides is also provided.

1.4.2.1 System Side Operation

On the system side, the IPBus Bridge operates at core frequency and fully supports pipelined communication with the core. The bridge acts as a slave device on this bus. The bridge is responsible for initiating IPBus transactions only per requests initiated by the core, or other system bus masters.

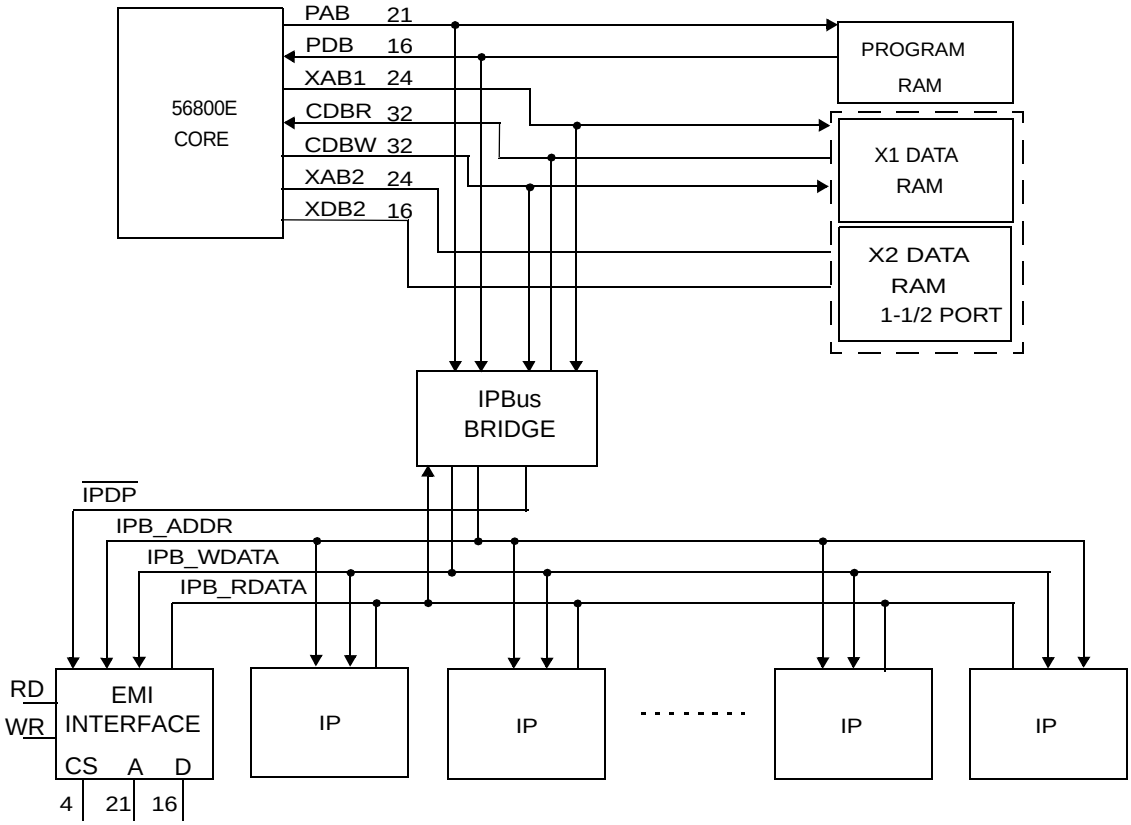


Figure 1-1. IPBus Bridge Interface With Other Main Components System Side Operation

1.4.2.2 Peripheral Side Operation

On the peripheral side, the IPBus Bridge accesses various devices through a standard non-pipelined IPBus interface. Separate bus lines are used for read and write transactions. The IPBus Bridge also interfaces with an External Memory Interface (EMI) block. The IPBus operates at half of the core frequency.

1.5 56852 Memory

The 56852 Memory module features:

- Harvard architecture permits as many as three simultaneous accesses to program and data memory
- On-chip memory includes:
  - 6K × 16-bit Program SRAM
  - 4K × 16-bit Data SRAM
  - 1K × 16-bit Boot ROM
- Up to 21-External Memory Address lines, 16-data lines and up to 4-programmable chip select signals

1.6 56852 Peripheral Blocks

The peripheral blocks on the 56852 provide:

- Four general purpose, 16-bit timers with two external pins*
- One Serial Communication Interface (SCI)*
- One Serial Port Interface (SPI)*
- Interrupt Controller
- Watchdog Timer (COP)
- JTAG/Enhanced On-Chip Emulation (EOnCE) for unobtrusive, real-time debugging
- Up to 11-GPIO

* Each peripheral I/O can be used alternately as a general purpose I/O if they are not needed

1.6.1 Energy Information

- Fabricated in high-density CMOS with 3.3V, TTL-compatible digital inputs
- Wait and Stop modes available

1.6.2 COP/Watchdog Timer Module

The Computer Operating Properly (COP) module provides the Watchdog timer functions. This function monitors processor activity and provides an automatic reset signal if a failure occurs.

- 160-bit counter, providing $(65536)^{10}$ different time-out periods
- COP timebase is the OSC clock divided by 128
- At 4MHz, minimum time-out period is 32µs, maximum is 2.1sec, with a resolution of 32µs

1.6.3 Peripheral Interrupts/Interrupt Controller Module

The peripherals on the 56852 use the interrupt channels found on the 56800E core. Each peripheral has its own interrupt vector (often more than one interrupt vector for each peripheral), and can selectively be enabled or disabled via the IPR found on the core. The Interrupt Controller (ITCN) module design includes these distinctive features:

- Programmable priority levels for each IRQ
- Two programmable Fast Interrupts
- Notification to the SIM module to restart clocks out of Wait and Stop modes.

1.6.4 Serial Communications Interface Module (SCI)

The SCI module allows asynchronous serial communications with peripheral devices and other Microcontroller Units (MCUs). SCI features include:

- Full-duplex or single wire operation
- Standard mark/space Non-Return-to-Zero (NRZ) format
- 13-bit baud rate selection
- Programmable 8-bit or 9-bit data format
- Separately enabled transmitter and receiver
- Separate receiver and transmitter CPU interrupt requests
- Programmable polarity for transmitter and receiver
- Two receiver wake up methods
- Interrupt-driven operation with seven flags
- Receiver framing error detection
- Hardware parity checking
- 1/16 bit-time noise detection

1.6.5 Serial Peripheral Interface Module (SPI)

The Serial Peripheral Interface (SPI) is an independent serial communications subsystem allowing full-duplex, synchronous, serial communication between the controller and peripheral devices, including other controllers. Software can poll SPI status flags or SPI operation can be interrupt driven. This block contains four 16-bit memory mapped registers for control parameters, status, and data transfer.

The 56852 has one, 4-pin SPI alternately used as GPIO when the SPI is not required. The SPI features include:

- Full-duplex operation
- Master and Slave modes
- Double-buffered operation with separate transmit and receive registers
- Programmable length transmissions (2 to 16 bits)
- Programmable transmit and receive shift order (MSB first or last bit transmitted)
- Eight Master mode frequencies (maximum = IPBus frequency ÷ 2)
- Maximum Slave mode frequency = IPBus frequency
- Clock ground for reduced Radio Frequency (RF) interference
- Serial clock with programmable polarity and phase
- Two separately enabled interrupts
  - SPRF (SPI Receiver Full)
  - SPTE (SPI Transmitter Empty)
- Mode fault error flag interrupt capability
- Wired OR mode functionality to enabling connection to multiple SPIs

1.6.6 Improved Synchronous Serial Interface Module (ISSI)

The ISSI is a full-duplex serial port designed to allow Digital Signal Controllers (DSCs) to communicate with a variety of serial devices, including industry-standard codecs, other controllers, microprocessors, and peripherals, including those implementing the Serial Peripheral Interface (SPI). It is typically used to transfer samples in a periodic manner. The ISSI consists of independent transmitter and receiver sections with independent clock generation and frame synchronization. Independent (asynchronous) or shared (synchronous) transmit and receive sections with separate or shared internal, external clocks and frame syncs. The Improved SSI (ISSI) features include:

- Independent (asynchronous) or shared (synchronous) transmit and receive sections with separate or shared internal/external clocks and frame syncs
- Normal mode operation using frame sync
- Network mode operation allowing multiple devices to share the port with as many as 32-time slots
- Gated Clock mode operation requiring no frame sync
- Programmable internal clock divider
- Programmable word length (8, 10, 12, or 16 bits)

- Program options for frame sync and clock generation
- ISSI power down feature
- Completely separate clock and frame sync selections for the receive and transmit sections

1.6.7 Quad Timer Module (TMR)

The Quad Timer (TMR) module has two external signals only available when the EMI A17/A18 are not in use. Otherwise, the two external signals of the module are capable of being used as either inputs or outputs. The two-pin Quad Timer provides the following features:

- Four 16-bit counters/timers
- Count up/down
- Counters can be cascaded
- Count modulo can be programmed
- Maximum count rate equals peripheral IPBus clock for external clocks
- Maximum count rate equals peripheral IPBus clock for internal clocks
- Count once or repeatedly
- Counters can be preloaded
- Counters can share available input pins
- Separate prescaler for each counter
- Each counter has capture and compare capability

1.6.8 General Purpose Input/Output Port (GPIO)

There are no GPIO interrupts on the 56852.

- Up to 11 shared GPIO, multiplexed with other peripherals
- Each bit can be individually configured as an input or output
- Selectable enable for pull-up resistors

1.6.9 Resets

The 56852 chip reset circuitry features:

- Integrated POR release occurs when the core V_{DD} exceeds 1.8V.

Chapter 2
Pin Descriptions

2.1 Introduction

The 56852 is available in an 81-pin MAPBGA package. There are 10-power pins, 10-ground pins, and 61-signal pins. Eleven of the signal pins can function either as a peripheral pin or a General Purpose Input/Output (GPIO) pin. The input and output signals of the 56852 are organized into functional groups, described in **Table 2-1** and illustrated in **Figure 2-1.** Each table row in **Table 2-2** describes the package pin and the signal(s) present.

2.2 Features

The interface signals have the following general characteristics:

- Pins pulled high with an on-chip resistor: TDI, TMS, $\overline{\text{TRST}}$, and $\overline{\text{DE}}$
- Pins pulled low with an on-chip resistor: TCK
- Pins pulled high by the device during hardware reset: $\overline{\text{RD}}$, $\overline{\text{WR}}$

All power and ground pins should be connected to the appropriate low-impedance power and ground paths.

Table 2-1. Functional Group Pin Allocations

Functional Group	Number of Pins
Power (V_{DD}, V_{DDIO}, or V_{DDA})	10[1]
Ground (V_{SS}, V_{SSIO}, or V_{SSA})	10[1]
Phase Lock Loop (PLL) and Clock	2[2]
External Bus Signals	39[3]
External Chip Select*	3[4]
Interrupt and Program Control	3[5]
Synchronous Serial Interface (SSI) Port*	6
Serial Communications Interface (SCI) Port*	2
Serial Peripheral Interface (SPI) Port	0[6]
Quad Timer Module Port	0[7]
JTAG/Enhanced On-Chip Emulation (EOnCE)	6

*Alternately, GPIO pins

1. $V_{DD} = V_{DD\ CORE}$, $V_{SS} = V_{SS\ CORE}$, $V_{DDIO} = V_{DD\ IO}$, $V_{SSIO} = V_{SS\ IO}$, $V_{DDA} = V_{DD\ ANA}$, $V_{SSA} = V_{SS\ ANA}$
2. CLKOUT is muxed Address pin A20.
3. Four Address pins are multiplexed with the timer, $\overline{CS3}$ and CLKOUT pins.
4. CS3 is multiplexed with external Address Bus pin A19.
5. Mode pins are multiplexed with External Data pins D13-D15 like A17and A18.
6. Four of these pins are multiplexed with SSI.
7. Two of these pins are multiplexed with 2 bits of the External Address Bus A17and A18.

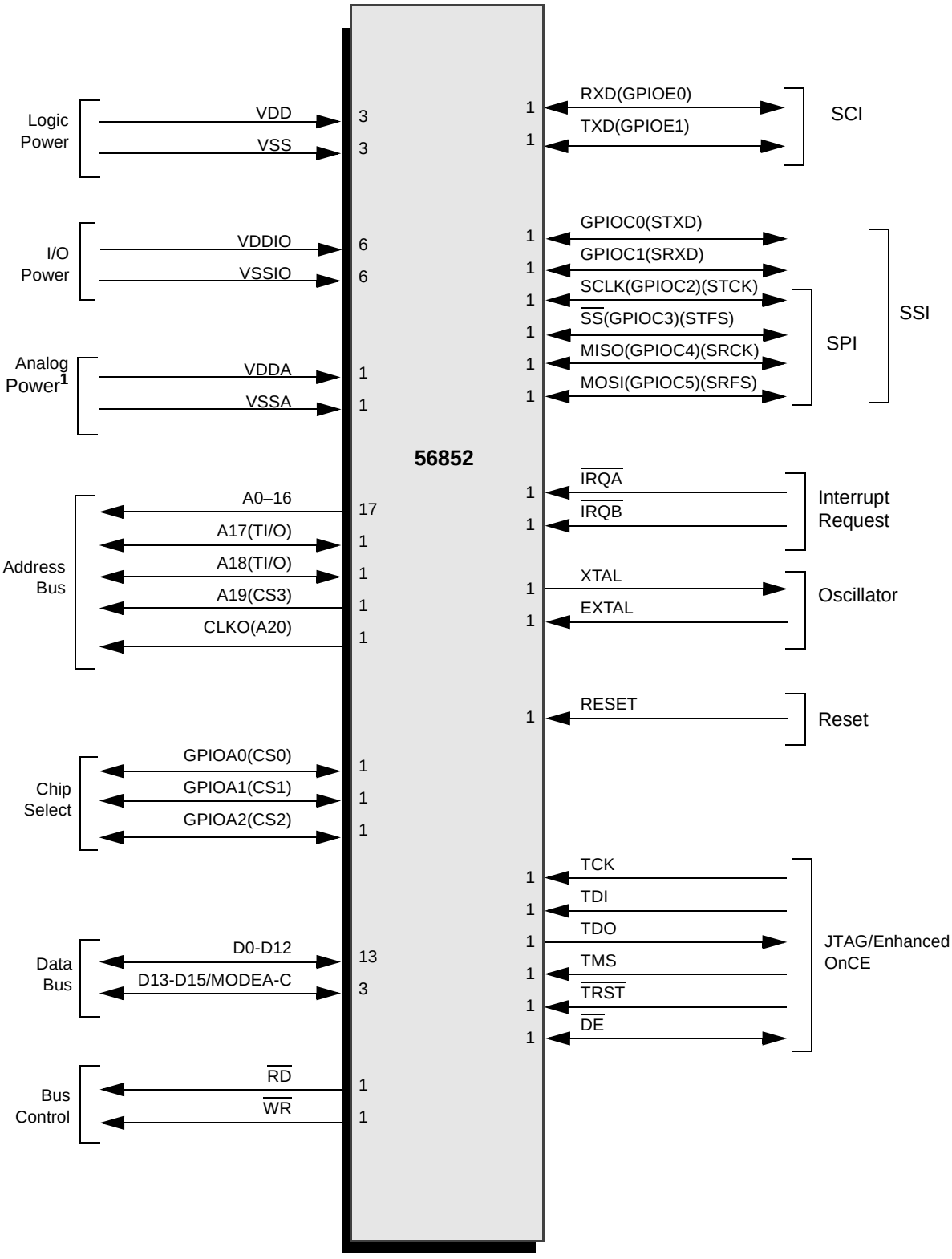


Figure 2-1. 56852 Signals Identified by Functional Group

1. Specifically for PLL, OSC, and POR.

2. Alternate pin functions are shown in parentheses.

2.3 Signal and Package Information

All digital inputs have a weak internal pull-up circuit associated with them. These pull-up circuits are enabled by default. Exceptions:

1. When a pin has GPIO functionality, the pull-up may be disabled under software control.
2. Mode pins D13, D14 and D15 have no pull-up.
3. TCK has a weak pull-down circuit always active.
4. Bidirectional I/O pullups automatically disable when the output is enabled.

This table is presented consistently with the *Signals Identified by Functional Group* figure.

1. **BOLD** entries in the *Type* column represents the state of the pin just out of reset.
2. Ouput(Z) means an output in a High-Z condition.

Table 2-2. 56852 Signal and Package Information for the 81-pin MAPBGA

Pin No.	Signal Name	Type	Description
E1	V_{DD}	V_{DD}	**Logic Power** —These pins provide power to the internal structures of the chip, and should all be attached to V_{DD}.
J5	V_{DD}		
E9	V_{DD}		
D1	V_{SS}	V_{SS}	**Logic Power - GND**—These pins provide grounding for the internal structures of the chip and should all be attached to V_{SS}.
J4	V_{SS}		
F9	V_{SS}		
C1	V_{DDIO}	V_{DDIO}	**I/O Power** —These pins provide power for all I/O and ESD structures of the chip, and should all be attached to V_{DDIO}.
H1	V_{DDIO}		
J7	V_{DDIO}		
G9	V_{DDIO}		
B9	V_{DDIO}		
A4	V_{DDIO}		
B1	V_{SSIO}	V_{SSIO}	**I/O Power - GND**—These pins provide grounding for all I/O and ESD structures of the chip and should all be attached to V_{SS}.
G1	V_{SSIO}		
J6	V_{SSIO}		
J9	V_{SSIO}		
C9	V_{SSIO}		
A5	V_{SSIO}		
B5	V_{DDA}	V_{DDA}	**Analog Power**—These pins supply an analog power source
B6	V_{SSA}	V_{SSA}	**Analog Ground**—This pin supplies an analog ground.

Table 2-2. 56852 Signal and Package Information for the 81-pin MAPBGA

Pin No.	Signal Name	Type	Description
E4	A0	Output(Z)	**Address Bus (A0–A16)—**These pins specify a word address for external program or data memory addresses.
F2	A1		
F3	A2		
F4	A3		
F1	A4		
G3	A5		
G2	A6		
J1	A7		
H2	A8		
H3	A9		
J2	A10		
H4	A11		
G4	A12		
J3	A13		
F5	A14		
H5	A15		
E5	A16		
F6	A17	**Output(Z)**	**Address Bus (A17)**
	TIO0	Input/Output	**Timer I/O (0)**—Can be programmed as either a timer input source or as a timer output flag.
G5	A18	**Output(Z)**	**Address Bus (A18)**
	TIO1	Input/Output	**Timer I/O (1)**—Can be programmed as either a timer input source or as a timer output flag.
H6	A19	**Output(Z)**	**Address Bus (A19)**
	$\overline{CS3}$	Output	**External Chip Select 3** —When enabled, a $\overline{CSx}$ signal is asserted for external memory accesses that fall within a programmable address range.
J8	CLKO	**Output**	**Output clock (CLKO)**—User programmable clock out reference
	A20	Output	**Address Bus—A20**
D2	$\overline{CS0}$	**Output**	**Chip Select 0 ($\overline{CS0}$)** —When enabled, a $\overline{CSx}$ signal is asserted for external memory accesses that fall within a programmable address range.
	GPIOA0	Input/Output	**Port A GPIO (0)** —A general purpose IO pin.

Table 2-2. 56852 Signal and Package Information for the 81-pin MAPBGA

Pin No.	Signal Name	Type	Description
D3	$\overline{CS1}$	**Output**	**Chip Select 1 ($\overline{CS1}$)** —When enabled, a $\overline{CSx}$ signal is asserted for external memory accesses that fall within a programmable address range.
	GPIOA1	Input/Output	**Port A GPIO (1)** —A general purpose IO pin.
C3	$\overline{CS2}$	**Output**	**Chip Select 2 ($\overline{CS2}$)**—When enabled, a $\overline{CSx}$ signal is asserted for external memory accesses that fall within a programmable address range.
	GPIOA2	Input/Output	**Port A GPIO (2)** —A general purpose IO pin.
G7	D0	**Input**/Output	**Data Bus (D0–D12)** —specify the data for external program or data memory accesses. D0–D15 are tri-stated when the external bus is inactive.
H7	D1		
H8	D2		
G8	D3		
H9	D4		
F8	D5		
F7	D6		
G6	D7		
E8	D8		
E7	D9		
E6	D10		
D8	D11		
D7	D12		
D9	D13 MODE A	**Input**/Output	**Data Bus (D13–D15)** — specify the data for external program or data memory accesses. D0–D15 are tri-stated when the external bus is inactive. **Mode Select**—During the bootstrap process the MODE A, MODE B, and MODE C pins select one of the eight bootstrap modes. These pins are sampled at the end of reset. **Note:** Any time POR and EXTERNAL resets are active, the state of MODE A, B and C pins get asynchronously transferred to the SIM Control Register [14:12] ($1FFF08) respectively. These bits determine the mode in which the part will boot up. **Note:** Software and COP resets do not update the SIM Control Register.
C8	D14 MODE B		
A9	D15 MODE C		

Table 2-2. 56852 Signal and Package Information for the 81-pin MAPBGA

Pin No.	Signal Name	Type	Description
E2	$\overline{RD}$	Output	**Bus Control– Read Enable ($\overline{RD}$)**—is asserted during external memory read cycles. When $\overline{RD}$ is asserted low, pins D0–D15 become inputs and an external device is enabled onto the data bus. When $\overline{RD}$ is deasserted high, the external data is latched inside the controller. $\overline{RD}$ can be connected directly to the $\overline{OE}$ pin of a Static RAM or ROM.
E3	$\overline{WR}$	Output	**Bus Control–Write Enable ($\overline{WR}$)**— is asserted during external memory write cycles. When $\overline{WR}$ is asserted low, pins D0–D15 become outputs and the controller puts data on the bus. When $\overline{WR}$ is deasserted high, the external data is latched inside the external device. When $\overline{WR}$ is asserted, it qualifies the A0–A15 pins. $\overline{WR}$ can be connected directly to the $\overline{WE}$ pin of a Static RAM.
B4	RXD GPIOE0	**Input** Input/Output	**SCI Receive Data (RXD)—**This input receives byte-oriented serial data and transfers it to the SCI receive shift register. **Port E GPIO (0)**—A general purpose I/O pin.
D4	TXD GPIOE1	**Output(Z)** Input/Output	**SCI Transmit Data (TXD)—**This signal transmits data from the SCI transmit data register. **Port E GPIO (1)**—A general purpose I/O pin.
B2	GPIOC0 STXD	**Input**/Output **Output**	**Port C GPIO (0)**—This pin is a General Purpose I/O (GPIO) pin when the SSI is not in use. **SSI Transmit Data (STXD)—**This output pin transmits serial data from the SSI Transmitter Shift Register.
A2	GPIOC1 SRXD	**Input**/Output **Input**	**Port C GPIO (1)**—This pin is a General Purpose I/O (GPIO) pin when the SSI is not in use. **SSI Receive Data (SRXD)—**This input pin receives serial data and transfers the data to the SSI Receive Shift Register.
A3	SCLK GPIOC2 STCK	**Input**/Output Input/Output Input/Output	**SPI Serial Clock (SCLK)**—In Master mode, this pin serves as an output, clocking slaved listeners. In Slave mode, this pin serves as the data clock input. **Port C GPIO (2)**—This pin is a General Purpose I/O (GPIO) pin that can individually be programmed as input or output pin. **SSI Serial Transfer Clock (STCK)—**This bidirectional pin provides the serial bit rate clock for the transmit section of the SSI. The clock signal can be continuous or gated.

Table 2-2. 56852 Signal and Package Information for the 81-pin MAPBGA

Pin No.	Signal Name	Type	Description
B3	$\overline{SS}$	**Input**	**SPI Slave Select ($\overline{SS}$)**—In Master mode, this pin is used to arbitrate multiple masters. In Slave mode, this pin is used to select the slave.
	GPIOC3	Input/Output	**Port C GPIO (3)**—This pin is a General Purpose I/O (GPIO) pin that can individually be programmed as input or output pin.
	STFS	Input/Output	**SSI Serial Transfer Frame Sync (STFS) —**This bidirectional pin is used to count the number of words in a frame while transmitting. A programmable frame rate divider and a word length divider are used for frame rate sync signal generation.
C4	MISO	**Input**/Output	**SPI Master In/Slave Out (MISO)**—This serial data pin is an input to a master device and an output from a slave device. The MISO line of a slave device is placed in the high-impedance state if the slave device is not selected.
	GPIOC4	Input/Output	**Port C GPIO (4)**—This pin is a General Purpose I/O (GPIO) pin that can individually be programmed as input or output pin.
	SRCK	Input/Output	**SSI Serial Receive Clock (SRCK)—**This bidirectional pin provides the serial bit rate clock for the receive section of the SSI. The clock signal can be continuous or gated.
C5	MOSI	Input/ **Output (Z)**	**SPI Master Out/Slave In (MOSI)**—This serial data pin is an output from a master device and an input to a slave device. The master device places data on the MOSI line a half-cycle before the clock edge that the slave device uses to latch the data.
	GPIOC5	Input/Output	**Port C GPIO (5)**—This pin is a General Purpose I/O (GPIO) pin that can individually be programmed as input or output pin.
	SRFS	Input/Output	**SSI Serial Receive Frame Sync (SRFS)**— This bidirectional pin is used to count the number of words in a frame while receiving. A programmable frame rate divider and a word length divider are used for frame rate sync signal generation.
A1	$\overline{IRQA}$	Input	**External Interrupt Request A ($\overline{IRQA}$)**—The $\overline{IRQA}$ Schmitt trigger input is a synchronized external interrupt request that indicates that an external device is requesting service. It can be programmed to be level-sensitive or negative-edge-triggered.
C2	$\overline{IRQB}$	Input	**External Interrupt Request B ($\overline{IRQB}$)**—The $\overline{IRQB}$ Schmitt trigger input is an external interrupt request that indicates that an external device is requesting service. It can be programmed to be level-sensitive or negative-edge-triggered.

Table 2-2. 56852 Signal and Package Information for the 81-pin MAPBGA

Pin No.	Signal Name	Type	Description
A6	EXTAL	Input	**External Crystal Oscillator Input (EXTAL)**—This input should be connected to an external crystal. If an external clock source other than a crystal oscillator is used, EXTAL must be tied off.
A7	XTAL	Input/**Output**	**Crystal Oscillator Output (XTAL)**—This output connects the internal crystal oscillator output to an external crystal. If an external clock source other than a crystal oscillator is used, XTAL must be used as the input.
D5	$\overline{\text{RESET}}$	Input	**Reset ($\overline{\text{RESET}}$)**—This input is a direct hardware reset on the processor. When $\overline{\text{RESET}}$ is asserted low, the controller is initialized and placed in the Reset state. A Schmitt trigger input is used for noise immunity. When the $\overline{\text{RESET}}$ pin is deasserted, the initial Chip Operating mode is latched from the D[15:13] pins. The internal reset signal will be deasserted synchronous with the internal clocks, after a fixed number of internal clocks. To ensure complete hardware reset, $\overline{\text{RESET}}$ and $\overline{\text{TRST}}$ should be asserted together. The only exception occurs in a debugging environment when a hardware reset is required and it is necessary not to reset the JTAG/Enhanced OnCE module. In this case, assert $\overline{\text{RESET}}$, but do not assert $\overline{\text{TRST}}$.
C6	TCK	Input	**Test Clock Input (TCK)**—This input pin provides a gated clock to synchronize the test logic and shift serial data to the JTAG/Enhanced OnCE port. The pin is connected internally to a pull-down resistor.
B7	TDI	Input	**Test Data Input (TDI)**—This input pin provides a serial input data stream to the JTAG/Enhanced OnCE port. It is sampled on the rising edge of TCK and has an on-chip pull-up resistor.
A8	TDO	Output	**Test Data Output (TDO)**—This tri-statable output pin provides a serial output data stream from the JTAG/Enhanced OnCE port. It is driven in the Shift-IR and Shift-DR controller states, and changes on the falling edge of TCK.
C7	TMS	Input	**Test Mode Select Input (TMS)**—This input pin is used to sequence the JTAG TAP controller's state machine. It is sampled on the rising edge of TCK and has an on-chip pull-up resistor.

Table 2-2. 56852 Signal and Package Information for the 81-pin MAPBGA

Pin No.	Signal Name	Type	Description
D6	$\overline{\text{TRST}}$	Input	**Test Reset ($\overline{\text{TRST}}$)**—As an input, a low signal on this pin provides a reset signal to the JTAG TAP controller. To ensure complete hardware reset, $\overline{\text{TRST}}$ should be asserted whenever $\overline{\text{RESET}}$ is asserted. The only exception occurs in a debugging environment, since the Enhanced OnCE/JTAG module is under the control of the debugger. In this case it is not necessary to assert $\overline{\text{TRST}}$ when asserting $\overline{\text{RESET}}$. Outside of a debugging environment $\overline{\text{RESET}}$ should be permanently asserted by grounding the signal, thus disabling the Enhanced OnCE/JTAG module on the controller.
B8	$\overline{\text{DE}}$	**Input**/Output	**Debug Even ($\overline{\text{DE}}$)**— is an open-drain, bidirectional, active low signal. As an input, it is a means of entering Debug mode of operation from an external command controller. As an output, it is a means of acknowledging that the chip has entered Debug mode.

Chapter 3
Memory (MEM)

3.1 Introduction

The 56800E core provides separate memory areas for program and data. The program area has a 21-bit address range; the data area has a 24-bit address range. Each area has a data width of 16 bits. The active areas in the 56852 memory include:

- 6K × 16-bit Program SRAM
- 4K × 16-bit Data SRAM
- 1K × 16-bit Boot ROM
- Up to 21 external memory address lines and 16-data lines, with up to four programmable chip select signals.
- Off-chip memory expansion capability up to 2M words × 16 program or 6M words × 16 data

3.2 Program Boot ROM

The 56852 has 1K-word × 16-bit on-chip Program ROM. The program ROM contains the bootstrap firmware program performing initial loading of the internal program RAM. It is located in program memory space at locations $1F0000-$1F03FF. The bootstrap program can load any Program RAM segment from an external memory or serial EEPROM. On exiting the reset state the first instruction is fetched from the program ROM ($1F0000) to start execution of the bootstrap program.

This boot loader assumes the external clock is being applied at a frequency between 2MHz and 4MHz. For some external devices, it enables the PLL during boot loading but always leaves the PLL off when complete.

The bootstrap program will perform one of several boot actions based on the value of BOOT_MODE in the SIM Control (SIM_CNTL) register. The value of this field is modified in two ways. First, it can be written by application code. Second, it is set to the three bit value of the input pins, MODA, MODB, and MODC at power-on or any time the $\overline{\text{RESET}}$ input is asserted. Other causes of reset including software reset and COP reset, being under the control of the application’s software, will therefore boot according to the value in the BOOT_MODE field prior to the assertion of that reset.

Boot modes 0, 1, and 6 transfer code to internal PRAM for execution and require header data to synchronize the peripheral, define the transfer start address in PRAM, defining the number of words to load. The following four points describe the data sequence when downloading the user program:

1. The 4-byte ASCII sequence *BOOT* (Boot mode 1 only)
2. Two words (4 bytes) defining the number of program words to be loaded (Boot modes 0, 1, and 6 only)
3. The number of program words (two bytes for each 16-bit program word) specified in Step 1 will be loaded into internal program memory starting at the address specified in Step 2 and continuing incrementally.
4. Once the bootstrap program completes loading the specified number of words, it jumps to the starting address and executes the loaded program.

The four-byte string *BOOT*, $42, $4F, and $54, loads B first in Boot mode 1. The bytes/words for the remaining data are loaded least significant byte/word first. The boot code is general-purpose and assumes the number of program words and starting address are valid for the users system. If the values are invalid, unpredictable results will occur. If a reserved mode is specified, the *debughlt* instruction will be executed, causing the software to enter an infinite loop.

Once the bootstrap program completes loading the specified number of words, if applicable to that Boot mode, it jumps to the starting address to execute the loaded program.

Some of the bootstrap routines reconfigure the memory map by setting the PRAMDBL and/or DRAMDBL fields. Some bootstrap routines also make specific assumptions about the external clock frequency being applied to the part. For some Boot modes, it enables the PLL during boot loading but always leaves the PLL off when complete.

3.2.1 Boot Mode 0: Bootstrap From Byte-Wide External Memory

The bootstrap program loads program memory from a byte-wide memory located at $040000 using $\overline{CS0}$ as the chip select, before jumping to the start of the user code.

3.2.2 Boot Mode 1: Bootstrap From SPI

The PRAMDBL and DRAMDBL remain zero, leaving both internal program and data RAM enabled. The bootstrap program loads program memory from a serial EEPROM via the SPI. GPIOC3 is an alternative function of the Slave Select ($\overline{SS}$). When configured and programmed, the alternative function can be used as the $\overline{SS}$ output. This mode is compatible with ATMEL AT25xxx and AT45xxx series serial EEPROMs.

In order to determine the correct SPI configuration, the first four bytes in the serial memory must be the string BOOT in ASCII. They are: $42, $4F, $4F, and $54. If, after trying all three configurations, BOOT is not read, the *debughlt* instruction will be executed causing the software to enter an infinite loop. After the string BOOT, the data should continue as described in the data sequence above. After loading the user program, GPIOC3 is returned to its Power-On Reset

state—input under peripheral control—and the bootstrap program jumps to the start of the user code. This boot loader assumes the external clock is being applied at a frequency between 2MHz and 4MHz.

3.2.3 Boot Mode 2: Normal Expanded Mode

No code is loaded. The bootstrap program simply vectors to external program memory location P:$040000 using $\overline{CS0}$ as the chip select.

3.2.4 Boot Mode 3: Development Expanded Mode

The PRAMDBL will be set to one and the DRAMDBL will remain zero, leaving internal data RAM enabled, but the internal program RAM is disabled. All references to internal program memory space are subsequently directed to external program memory. No code is loaded. The bootstrap program simply vectors to program memory location P:$000000 using $\overline{CS0}$ as the chip select.

3.2.5 Boot Mode 4: Bootstrap From Host Port–Single Strobe Clocking

The PRAMDBL and DRAMDBL remain zero, leaving both internal program and data RAM enabled. The bootstrap program configures the host port for single strobe access, loading program memory from the host port before jumping to the start of the user code.

3.2.6 Boot Mode 5: Bootstrap From Host Port–Dual Strobe Clocking

The bootstrap program configures the host port for dual strobe access, loading program memory from the host port before jumping to the start of the user code.

3.2.7 Boot Mode 6: Bootstrap From SCI

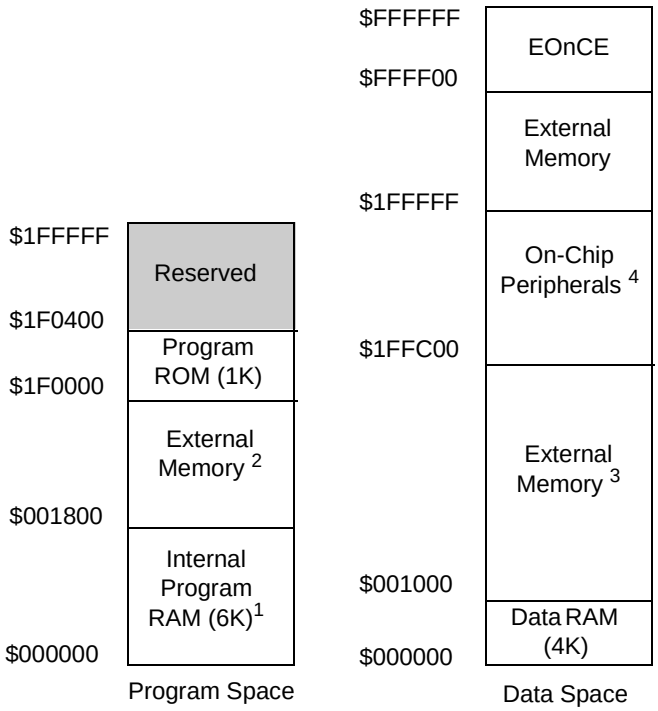
It configures the SCI for 38400 baud transfers with a 4MHz or 19200 with 2MHz crystals. It also enables the PLL to operate during the boot process. The bootstrap program then loads program memory from the SCI port and jumps to the start of the user code. External clocking must be between 2MHz and 4MHz. It uses the PLL but leaves it off when complete. The data format is:

- One start bit
- Eight-data bits
- No parity bit
- One Stop bit
- Flow Control off

3.2.8 Boot Mode 7: Reserved for Future Use

3.3 Memory Map

The 56852 memory areas are illustrated in **Figure 3-1.**



1. In operating mode three, chip select zero is initially set to P:$000000 - $07FFFF and the internal PRAM will be disabled.
2. In operating mode two, chip select zero is initially set to P:$040000 - $7FFFF.
3. In operating mode zero, chip select zero is initially set to X:$040000 - $07FFFF.
4. The range of short I/O space is: $1FFFC0 - $1FFFFF.

Figure 3-1. 56852 Memory Map

Note: The data (X) address space for all parts is actually 24 bits ($000000 - $FFFFFF) but only 21 bits are brought out externally. The chip selects can be programmed to allow data accesses above $1FFFFF. In this case the data space can be thought of as multiple 2M word pages.

3.3.1 Memory Register Summary

All accessible Enhanced OnCE (EOnCE) memory mapped registers available in the 56852 are listed in **Table 3-1.** Peripheral System Configuration registers required to control or access the peripherals are detailed in **Table 3-7** through **Table 3-8,** and are fully described in the each of their individual peripheral chapters.

Table 3-1. EOnCE Memory Map (EOnCE_BASE = $FFFF00)

Register Acronym	Address Offset	Register Description
OTX1/ORX1	$FF	Transmit Register Upper Word Receive Register Upper Word
OTX/ORX	$FE	Transmit Register Receive Register
OTXRXSR	$FD	Transmit and Receive Status and Control Register
OCLSR	$FC	Core Lock/Unlock Status Register
		Reserved
OCR	$A0	Control Register
—	$9F	Instruction Step Counter
OSCNTR	$9E	Instruction Step Counter
OSR	$9D	Status Register
OBASE	$9C	Peripheral Base Address Register
OTBCR	$9B	Trace Buffer Control Register
OTBPR	$9A	Trace Buffer Pointer Register
—	$99	Trace Buffer Register Stages
OTB	$98	Trace Buffer Register Stages
—	$97	Breakpoint Unit [0] Control Register
OBCR	$96	Breakpoint Unit [0] Control Register
—	$95	Breakpoint 1 Unit [0] Address Register
OBAR1	$94	Breakpoint 1 Unit [0] Address Register
—	$93	Breakpoint 2 Unit [0] Address Register
OBAR2	$92	Breakpoint 2 Unit [0] Address Register
—	$91	Breakpoint 1 Unit [0] Mask Register
OBMSK	$90	Breakpoint 1 Unit [0] Mask Register
		Reserved
OBCNTR	$8E	EOnCE Breakpoint Unit [0] Counter
		Reserved

3.3.1.1 Peripheral Mapped Registers

Table 3-7 through Table 3-8 lists all individual Peripheral Memory mapped registers in the 56852 package. Individual peripheral register address maps are located in the following tables.

Table 3-2. System Integration Module Registers Address Map (SYS_BASE = $1FFF08)

Register Acronym	Address Offset	Register Description
SIMCTL	$0	SIM Control Register
		Reserved
		Reserved
SIMCR	$3	SIM Configuration Register

Table 3-3. External Memory Interface Registers Address Map (EMI_BASE = $1FFE40)

Register Acronym	Address Offset	Register Description
CSBAR_0	$0	CS Base Address & Block Size Register
CSBAR_1	$1	CS Base Address & Block Size Register
CSBAR_2	$2	CS Base Address & Block Size Register
CSBAR_3	$3	CS Base Address & Block Size Register
CSOR_0	$8	CS Options Register
CSOR_1	$9	CS Options Register
CSOR_2	$A	CS Options Register
CSOR_3	$B	CS Options Register
BCR	$10	Bus Control Register

Table 3-4. Clock Generation Module Registers Address Map (CGM_BASE = $1FFF10)

Register Acronym	Address Offset	Register Description
CGMCR	$0	CGM Control Register
CGMDB	$1	CGM Divide-By Register
CGMTOD	$2	CGM Time of Day Register
CGMTST	$3	CGM Test Register

Table 3-5. Interrupt Control Registers Address Map (ITCN_BASE = $1FFF20)

Register Acronym	Address Offset	Register Description
IPR0	$0	Interrupt Priority Register 0

Table 3-5. Interrupt Control Registers Address Map (ITCN_BASE = $1FFF20)

Register Acronym	Address Offset	Register Description
IPR1	$1	Interrupt Priority Register 1
IPR2	$2	Interrupt Priority Register 2
IPR3	$3	Interrupt Priority Register 3
IPR4	$4	Interrupt Priority Register 4
IPR5	$5	Interrupt Priority Register 5
IPR6	$6	Interrupt Priority Register 6
IPR7	$7	Interrupt Priority Register 7
VBA	$8	Vector Base Address Register
FIM0	$9	Fast Interrupt Match Register 0
FIVAL0	$A	Fast Interrupt Vector Address Low 0 Register
FIVAH0	$B	Fast Interrupt Vector Address High 0 Register
FIM1	$C	Fast Interrupt Match Register 1
FIVAL1	$D	Fast Interrupt Vector Address Low 1
FIVAH1	$E	Fast Interrupt Vector Address High 1
IRQP0	$F	IRQ Pending Register 0
IRQP1	$10	IRQ Pending Register 1
IRQP2	$11	IRQ Pending Register 2
IRQP3	$12	IRQ Pending Register 3
ICTL	$17	Interrupt Control Register

Table 3-6. Serial Communications Interface Registers Address Map (SCI_BASE = $1FFFE0)

Register Acronym	Address Offset	Register Description
SCIBR	$0	SCI Baud Rate Register
SCICR	$1	SCI Control Register
SCISR	$3	SCI Status Register
SCIDR	$4	SCI Data Register

Table 3-7. Serial Peripheral Interface Registers Address Map (SPI_BASE =$1FFFE8)

Register Acronym	Address Offset	Register Description
SPSCR	$0	SPI Status and Control Register
SPDSCR	$1	SPI Data Size and Control Register
SPDRR	$2	SPI Data Receive Register
SPDTR	$3	SPI Data Transmit Register

Table 3-8. Improved Synchronous Serial Interface Registers Address Map (ISSI_BASE = $1FFE20)

Register Acronym	Address Offset	Register Description
STX	$0	ISSI Transmit Register
SRX	$1	ISSI Receive Register
SCSR	$2	ISSI Control/StatusRegister
SCR2	$3	ISSI Control Register 2
STXCR	$4	ISSI Transmit Control Register
SRXCR	$5	ISSI Receive Control Register
STSR	$6	ISSI Time-Slot Register
SFCSR	$7	ISSI FIFO Control/Status Register
SOR	$9	ISSI Option Register

Table 3-9. Quad Timer Registers Address Map (TMR_BASE = $1FFE80)

Register Acronym	Address Offset	Register Description
TmrA0_Cmp1	$0	Compare Register 1
TmrA0_Cmp2	$1	Compare Register 2
TmrA0_Cap	$2	Capture Register
TmrA0_Load	$3	Load Register
TmrA0_Hold	$4	Hold Register
TmrA0_Cntr	$5	Counter Register
TmrA0_Ctrl	$6	Control Register
TmrA0_SCR	$7	Status and Control
TmrA1_Cmp1	$8	Compare Register 1
TmrA1_Cmp2	$9	Compare Register 2
TmrA1_Cap	$A	Capture Register
TmrA1_Load	$B	Load Register
TmrA1_Hold	$C	Hold Register
TmrA1_Cntr	$D	Counter Register
TmrA1_Ctrl	$E	Control Register
TmrA1_SCR	$F	Status and Control
TmrA2_Cmp1	$10	Compare Register 1
TmrA2_Cmp2	$11	Compare Register 2
TmrA2_Cap	$12	Capture Register
TmrA2_Load	$13	Load Register
TmrA2_Hold	$14	Hold Register
TmrA2_Cntr	$15	Counter Register
TmrA2_Ctrl	$16	Control Register
TmrA2_SCR	$17	Status and Control
TmrA3_Cmp1	$18	Compare Register 1
TmrA3_Cmp2	$19	Compare Register 2
TmrA3_Cap	$1A	Capture Register
TmrA3_Load	$1B	Load Register
TmrA3_Hold	$1C	Hold Register
TmrA3_Cntr	$1D	Counter Register
TmrA3_Ctrl	$1E	Control Register
TmrA3_SCR	$1F	Status and Control

Table 3-10. General Purpose Input/Output Port A Register Map (GPIOA_BASE = $1FFE60)

Register Acronym	Address Offset	Register Description
GPIO_A_PER	$0	Peripheral Enable Register
GPIO_A_DDR	$1	Data Direction Register
GPIO_A_DR	$2	Data Register
GPIO_A_PUR	$3	Pull-Up Enable Register

Table 3-11. General Purpose Input/Output Port C Register Map (GPIOC_BASE = $1FFE68)

Register Acronym	Address Offset	Register Description
GPIO_C_PER	$0	Peripheral Enable Register
GPIO_C_DDR	$1	Data Direction Register
GPIO_C_DR	$2	Data Register
GPIO_C_PUR	$3	Pull-Up Enable Register

Table 3-12. General Purpose Input/Output Port E Register Map (GPIOE_BASE = $1FFE70)

Register Acronym	Address Offset	Register Description
GPIO_E_PER	$0	Peripheral Enable Register
GPIO_E_DDR	$1	Data Direction Register
GPIO_E_DR	$2	Data Register
GPIO_E_PUR	$3	Pull-Up Enable Register

3.3.2 Interrupt Vectors

The interrupt vectors for the 56852 reside in program memory area. Default addresses of each vector is listed in the ITCN Chapter, **Section 8.9.9.**

Reset is considered to be the highest priority interrupt, taking precedence over all other interrupts. If the reset pin is pulled low, the interrupt controller generates a reset vector address for the core.

The reset vector for the 56852 is $1F0000, the start address of the internal boot ROM.

Chapter 4
System Integration Module (SIM)

4.1 Introduction

The System Integration Module (SIM) is responsible for system control functions listed below:

- Clock generation
- Reset generation
- Power mode control
- Boot mode control
- Memory map control
- Integrated Circuit (IC) configuration control
- External I/O configuration control
- Software control registers

4.2 Features

The SIM module provides these listed qualities:

- Four system bus clocks with pipeline hold-off support
  - Data RAM clock with hold-off control
  - IPBus Interface clock with hold-off control
  - Core system clock
  - General purpose clock (both standard and inverted versions)
- Three system clocks for non-pipelined interfaces
  - PCLK clock for core
  - NCLK clock for core
  - A continuously running system clock
- A peripheral bus (IPBus) clock, both standard and inverted versions
- An external clock output with disable
- A peripheral bus clock phase indicator
- Three power modes to control power utilization:
  - Stop mode shuts down core, system clocks, and peripheral bug clocks. Stop mode entry can optionally disable PLL and Oscillator (lowest power vs. fast restart).
  - Wait mode shuts down the core, and unnecessary system clock operation while peripherals continue to operate.

  - Run mode supports full part operation
- Controls to enable/disable the core Wait and Stop instructions
- 32-cycle extended synchronous resets for CGM, the core, and other system blocks
- Software initiated reset
- Controls to redirect internal data and/or program RAM accesses to the external memory interface
- Software Boot mode control register (initialized at any reset except COP reset from external pads)
- A hold-off output to coordinate the system and peripheral buses
- Two 16-bit software control registers reset only by a power-on reset usable for general purpose software control
- Eight bits to control external I/O configurations
- Features to support testing of the SIM and the IC
  - Scan test support
  - JTAG boundary scan
  - Peripheral Broadside Test mode

4.3 SIM Block Diagram

The System Integration Module (SIM) is depicted in **Table 4-1.**

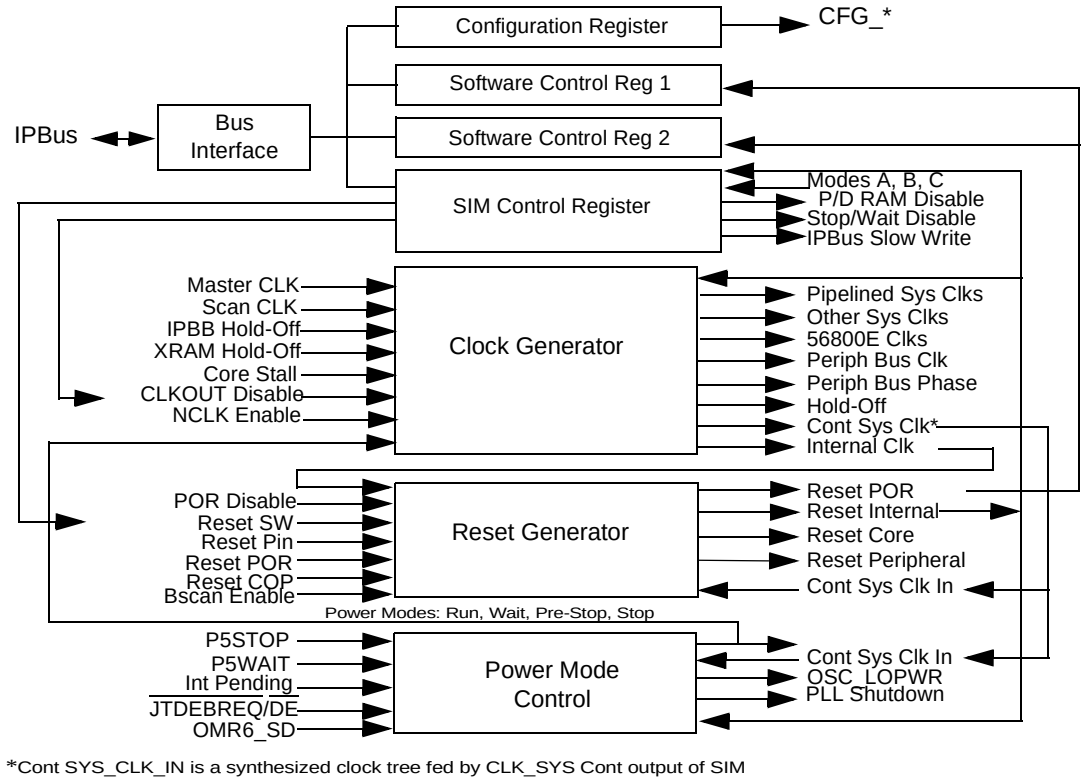


Figure 4-1. System Integration Module

4.4 Signal Description

A description of the System Integration Module (SIM) signals is listed in **Tables 4-1** through **Tables 4-6.**

4.4.1 SIM Interface Signals

Table 4-1. IPBus Signals

Name	Type	Clock Domain	Function
CLK_IPB	Input	—	Peripheral bus clock
RD_DATA_Z	Output	CLK_IPB	Read data (tri-stateable)
WR_DATA	Input	CLK_IPB	Write data
ADDR	Input	CLK_IPB	R/W address (two LSBs of IPBus Address)
RWB	Input	CLK_IPB	Write enable (active low)
$\overline{\text{MODULE\_EN}}$	Input	CLK_IPB	Module enable (active low)

Table 4-2. Reset Generator Inputs/Outputs

Name	Type	Clock Domain	Function
$\overline{\text{RST\_CORE}}$	Output	CLK_SYS_CONT	Synchronized and extended reset to core
$\overline{\text{RST\_PERIPH}}$	Output	CLK_SYS_CONT	Synchronized and extended reset to general peripheral logic
$\overline{\text{RST\_CGM}}$	Output	CLK_OSC	Synchronized and extended reset to CGM module
$\overline{\text{RST\_PIN}}$	Input	—	Reset request from external reset pin
$\overline{\text{RST\_POR}}$	Input	—	Reset request from power-on reset module
$\overline{\text{RST\_COP}}$	Input	—	Reset request from COP module

Table 4-3. Register Inputs/Outputs

Name	Type	Clock Domain	Function
MODE_CBA[2:0]	Input	—	From [15:13] input pads, captured at reset in SIM control register to indicate software boot mode
PRAM_DBL	Output	CLK_IPB	Redirect program RAM accesses to external memory IF
DRAM_DBL	Output	CLK_IPB	Redirect data RAM accesses to external memory IF
STOP_DBL	Output	CLK_IPB	Direct the core to disable the Stop instruction
WAIT_DBL	Output	CLK_IPB	Direct the core to disable the Wait instruction
CFG_CO	Output	CLK_IPB	Replace CLKOUT output with A[20] output
CFG_A19	Output	CLK_IPB	Replace A[19] output with $\overline{CS3}$ output
CFG_A18	Output	CLK_IPB	Replace A[18] output withTIO[1] output
CFG_A17	Output	CLK_IPB	Replace A[17] output with TIO[0] output
CFG_SCK	Output	CLK_IPB	Replace SCK output with STCK output
CFG_SSB	Output	CLK_IPB	Replace $\overline{SS}$ output with STFS output
CFG_MISO	Output	CLK_IPB	Replace MISO output with SRCK output
CFG_MOSI	Output	CLK_IPB	Replace MOSI output with SRFS output

Table 4-4. Power Mode Control Inputs/Outputs

Name	Type	Clock Domain	Function
STOPMD	Output	CLK_SYS_CONT	Indicates SIM is in Stop mode
WAITMD	Output	CLK_SYS_CONT	Indicates SIM is in Wait mode
RUNMD	Output	CLK_SYS_CONT	Indicates SIM is in Run mode
OSC_LOPWR	Output	CLK_SYS_CONT	Puts oscillator into Low Power mode configuration during Stop mode
PLL_SHUTDOWN	Output	CLK_SYS_CONT	Shuts down PLL and puts it into Bypass mode when entering Stop mode
P5STOP	Input	CLK_SYS_CONT	Input from the core indicating Stop instruction executed
P5WAIT	Input	CLK_SYS_CONT	Input from the core indicating Wait instruction executed
INT_PEND	Input	CLK_SYS_CONT	Input from INTC indicating interrupt is pending
JTDEBREQ	Input	CLK_SYS_CONT	Input from core indicating a JTAG Debug mode request
$\overline{DE}$	Input	CLK_SYS_CONT	Input from $\overline{DE}$ input pad used to enter OnCE Debug mode
OMR6_SD	Input	CLK_SYS_CONT	From core omr6 register to enable fast Stop mode recovery
BSCAN_EBL	Input	—	From external TAP controller indicating Boundary Scan mode

Table 4-5. Test Inputs/Outputs

Name	Type	Clock Domain	Function
TMODE_PSCAN	Input	CLK_SCAN	Indicates part is in peripheral Scan mode
TMODE_CSCAN	Input	CLK_SCAN	Indicates part is in core Scan mode
TMODE_BIST	Input	CLK_MSTR	Indicates part is in memory BIST Test mode
POR_DBL	Input	CLK_SYS_CONT	Override $\overline{\text{RST\_POR}}$ with $\overline{\text{RST\_PIN}}$ signal for test
CORE_STALL_TST	Input	CLK_MSTR	Disable core clock for test purposes
IPB_BTM_MODE	Input	CLK_MSTR	Indicates part is in IPBus Broadside Test mode

Table 4-6. Derived Clock Inputs

Name	Type	Clock Domain	Function
CLK_SYS_CONT_IN	Input	CLK_SYS_CONT	Continuous clock fed by synthesized clock tree originating at SIM output CLK_SYS_CONT

4.5 Module Memory Map

The System Integration Module (SIM) contains four programmable 16-bit registers. The address range from X:$1FFF08 to X:$1FFF0F is allocated to the SIM. The register accessed by each of the eight-memory mapped addresses is indicated in **Table 4-7.** A write to an address without an associated register is a *NOOP*. A read from an address without an associated register returns unknown data.

Table 4-7. SIM Module Memory Map (SIM_BASE =$FFF08)

Address Offset	Register Acronym	Register Name	Access Type	Chapter Location
Base + $0	SCR	SIM Control Register	Read/Write	**Section 4.6.1**
Base + $1	SCD1	Software Control Data Reg 1	Read/Write	**Section 4.6.2**
Base + $2	SCD2	Software Control Data Reg 2	Read/Write	**Section 4.6.3**
Base + $3	SCFGR	SIM Configuration Register	Read/Write	**Section 4.6.4**

Add. Offset	Register Name		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$0	SCR	R	0	BOOT MODE			CHIIP REV				0	EONCE EBL	CLKOUT DBL	PRAM DBL	DRAM DBL	SW RST	STOP DBL	WAIT DBL
		W																
$1	SCD1	R	SOFTWARE CONTROL DATA 1															
		W																
$2	SCD2	R	SOFTWARE CONTROL DATA 2															
		W																
$3	SCFGR	R									CFG CLKOUT	CFG A[19]	CFG A[18]	CFG A[17]	CFG SCLK	CFG $\overline{SS}$	CFG MISO	CFG MOSI
		W																

R	0	Read as 0
W		Reserved

Figure 4-2. SCI Register Map Summary

4.6 Register Descriptions (SYS_BASE = $1FFF08)

4.6.1 SIM Control Register (SCR)

Base + $0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	BOOT MODE			CHIIP REV				0	EOnCE EBL	CLKOUT DBL	PRAM DBL	DRAM DBL	SW RST	STOP DBL	WAIT DBL
Write																
Reset	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Figure 4-8. SIM Control Register (SCR)

See Programmer's Sheet on Appendix page B-6

4.6.1.1 Reserved—Bit 15

This bit is reserved or not implemented. It is read as 0, but cannot be modified by writing.

4.6.1.2 Boot Mode—Bits 14–12

Note: This field replaces the mode bits in the 56852 OMR.

This field is set to the value of external pads D[15:13] when the last active reset source reset pin, power-on reset, or software reset deasserts.

Note: A COP reset via $\overline{\text{RST\_COP}}$ does not alter these registers since a COP reset by definition occurs unexpectedly during system operation. Users may no longer be providing the required MODE_CBA inputs.

Note: A software reset via $\overline{\text{RST\_SW}}$ does not alter these registers, thereby allowing a reboot in a different mode without altering the hardware.

The 56800E core always begins execution from the base of the on-chip ROM. The software in ROM will perform one of several boot actions based on the value of BOOT MODE.

The bootstrap program expects the following prefix data-sequence when downloading the user program through an external port.

1. The 4-byte string $43, $4F, $4F, $54 (Boot mode 1 only)
2. Two words (4 bytes) defining the number of program words to be loaded (Boot modes 0, 1, and 6)
3. Two words (4 bytes) starting address the program memory will be loaded in by the user program (Boot modes 0, 1, and 6)

The user program follows two bytes for each 16-bit program word.

The bytes/words for each data sequence are loaded least significant byte/word first. The boot code is general-purpose and assumes the number of program words and starting address are valid for the users system. If the values are invalid then unpredictable results will occur. If a Reserved mode is specified, the 56800E DEBUGHLT instruction will be executed to place the core in Debug mode.

Once the bootstrap program completes loading the specified number of words, it jumps to the starting address to execute the loaded program. Some of the bootstrap routines also reconfigure the memory map by setting the PRAM Disable and/or DRAM Disable fields.

4.6.1.2.1 Boot Mode 0: Bootstrap from Byte Wide External Memory

The PRAM DISABLE and DRAM DISABLE fields are both left zero, leaving both internal program and Data RAM enabled. The Bootstrap program loads program memory from a byte-wide memory located at X:$040000 then jumps to the start of the user code.

4.6.1.2.2 Boot Mode 1: Bootstrap from SPI Port

The PRAM DISABLE and DRAM DISABLE remains zero, leaving both internal program and Data RAM enabled. The bootstrap program loads program memory from a serial EEPROM via the SPI. GPIOC3 is an alternative function of the $\overline{SS}$, which when configured and programmed, can be used as the $\overline{SS}$ output. This mode is compatible with ATMEL AT25xxx, AT25xxxx, and AT45xxx series serial EEPROMs. After loading the user program, GPIOC3 is returned to its power on reset state (input under peripheral control) and the Bootstrap program jumps to the start of the user code. Boot Mode 1 requires extra header data described in **Section 4.6.1.2.**

4.6.1.2.3 Boot Mode 2: Normal Expanded Mode

The PRAM DISABLE and DRAM DISABLE fields are both left zero, leaving both internal program and Data RAM enabled. No code is loaded. The Bootstrap program simply vectors to external program memory location P:$040000.

4.6.1.2.4 Boot Mode 3: Development Expanded Mode

The DRAM DISABLE field is left zero, but PRAM DISABLE is set to 1. This leaves the Internal Data RAM enabled but the Internal Program RAM disabled. All references to internal program memory space are subsequently directed to the external program memory. No code is loaded. The Bootstrap program simply vectors to program memory location P:$000000.

4.6.1.2.5 Boot Modes 4–5: Reserved

These bits are reserved for future use.

4.6.1.2.6 Boot Mode 6: Bootstrap from SCI Port

Mode 6 is one of the Bootstrap mode having all internal program and data RAM memories enabled. In Mode 6, the bootstrap program loads program memory from an asynchronous serial peripheral device via the SCI. This mode requires a specific crystal to be used with the PLL for clock generation. If a 4MHz crystal is used, the data rate of the SCI is 38400. Consequently, a 2MHz crystal yields a data rate of 19200. In future versions, a baud detection program with handshaking should be added. The data format is:

- One start bit
- Eight-data bits
- No parity bit
- One Stop bit
- Flow Control off

After loading the user program, the bootstrap program jumps to the start of the user code.

4.6.1.2.7 Reserved: Boot Mode 7

This bit is reserved for future use.

4.6.1.3 Reserved—Bits 11–7

Bits 11–8 are read only 0 and cannot be modified. Bit 7, however, can be modified and initializes to 1. It currently serves no functional purpose.

4.6.1.4 Enhanced OnCE Enable (OnCE_EBL)—Bit 6

Set if the Enhanced OnCE register I/O or other Enhanced OnCE features to be used from application software rather than the external debugger attached to the TAP interface.

- 0 = Enhanced OnCE clock to core enabled when the core TAP is enabled
- 1 = Enhanced OnCE clock to core is always enabled

4.6.1.5 CLKOUT Disable (CLKOUT_DBL)—Bit 5

- 0 = CLKOUT output pin presents CLK_MSTR/8 (this is half the peripheral bus clock frequency)
- 1 = CLKOUT output presents static zero

4.6.1.6 Program RAM Disable (PRAM_DBL)—Bit 4

- 0 = Internal program RAM enabled
- 1 = Internal program RAM disabled and accesses redirected to external memory

4.6.1.7 Data RAM Disable (DRAM_DBL)—Bit 3

- 0 = Internal data RAM enabled
- 1 = Internal data RAM disabled and accesses redirected to external memory

4.6.1.8 Software Reset (SW_RST)—Bit 2

Writing 1 to this field resets the part.

4.6.1.9 Stop Disable (STOP_DBL)—Bit 1

The Stop mode will be entered when the core executes a Stop instruction.

- 0 = The Stop instruction will cause entry into Stop mode
- 1 = The Stop instruction will not cause entry into Stop mode

4.6.1.10 Wait Disable (WAIT_DBL)—Bit 0

The Wait mode will be entered when the core executes a Wait instruction.

- 0 = The Wait instruction will cause entry into the Wait mode
- 1 = The Wait instruction will not cause entry into the Wait mode

4.6.2 SIM Software Control Data 1 (SCD1)

Base + $1	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	SOFTWARE CONTROL DATA 1															
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 4-9. SIM Software Control Data Register 1 (SCD1)

See Programmer's Sheet on Appendix page B-7

4.6.2.1 Software Control Data 1 (SSCR1)—Bits 15–0

This register is reset only by the Power-On Reset (POR). It has no part specific functionality and is intended for use by software developers to contain data to be unaffected by the other reset sources:

- Reset pin
- Software reset
- COP reset

4.6.3 Software Control Data 2 (SCD2)

Base + $2	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	SOFTWARE CONTROL DATA 2															
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 4-10. SIM Software Control Data Register 2 (SCD2)

See Programmer's Sheet on Appendix page B-7

4.6.3.1 Software Control Data 2 (SCD2)—Bits 15–0

This register is reset only by the Power-on Reset (POR). It has no part specific functionality and is intended for use by software developers to contain data to be unaffected by the other reset sources:

- Reset pin
- Software reset
- COP reset

4.6.4 SIM Configuration Register (SCFGR)

Base + $3	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read									CFG CLKOUT	CFG A[19]	CFG A[18]	CFG A[17]	CFG SCLK	CFG $\overline{SS}$	CFG MISO	CFG MOSI
Write																
Reset	0	0	0	0	0	0	0	0	0	0[1]	0	0	0	0	0	0

1. Since date code 0302, the ROM Bootcode of the device will change the setting of CFG A[19} to one. It will then be configured as $\overline{CS3}$ and be set to the inactive state, 1. Exercise care when using Boot Mode 2 taking this into consideration.

Figure 4-11. SIM Configuration Register (SCFGR)

See Programmer's Sheet on Appendix page B-8

The Configuration register determines which of two functional signals is connected to a specific bidirectional external I/O device during the normal (functional) operating mode of the part. These external I/O and the Configuration register bit fields are named for the signal connected to that I/O by default.

4.6.4.1 Reserved—Bits 15–8

These bits are reserved or not implemented. They cannot be read nor modified by writing.

4.6.4.2 Configure Clock Out (CFG_CLKOUT)—Bit 7

- 0 = CLKOUT (SIM)
- 1 = A[20] (EMI)

4.6.4.3 Configure A[19] Output (CFG_A[19])—Bit 6

- 0 = A[19] (EMI)
- 1 = $\overline{CS3}$ (EMI)

4.6.4.4 Configure A[18] Output (CFG_A[18])—Bit 5

- 0 = A[18] (EMI)
- 1 = TIO1 (TMR)

4.6.4.5 Configure A[17] Output (CFG_A[17])—Bit 4

- 0 = A[17] (EMI)
- 1 = TIO0 (TMR)

4.6.4.6 Configure Serial Clock (CFG_SCLK)—Bit 3

- 0 = SCK (SPI)
- 1 = STCK (SSI)

4.6.4.7 Configure Slave Select Output (CFG_$\overline{SS}$)—Bit 2

- 0 = $\overline{SS}$ (SPI)
- 1 = STFS (SSI)

4.6.4.8 Configure Master In/Slave Out (CFG_MISO)—Bit 1

- 0 = MISO (SPI)
- 1 = SRCK (SSI)

4.6.4.9 Configure Master Out/Slave In (CFG_MOSI)—Bit 0

- 0 = MOSI (SPI)
- 1 = SRFS (SSI)

4.7 Implementation

This section describes various implementation details of the SIM module. Specific sections are devoted to describing clock generation concepts, generated clocks, generated reset signals, and power mode control.

4.7.1 Clock Generation Concepts

The 56852 system bus is pipelined. The data cycle is when data is read or written. It occurs two system clock cycles after the address cycle with a *between* cycle separating the two. The SIM also supports the 56800E core system bus master. The SIM contains features to maintain the integrity of this continuous pipeline during the operation of the system. A hold-off mechanism is furnished to provide system bus slaves extra clock cycles when needed to maintain synchronization with the pipeline. All system bus clocks operate at one-half the frequency of CLK_MSTR.

The peripheral bus clock has no hold-off or stall. It runs at one-half the frequency of the system bus. The peripheral bus reads and writes are normally single cycle. The IPBB is the only master on the peripheral bus. A peripheral bus transaction is two system bus-cycles long. The first half of a peripheral bus-cycle is the address phase when the address is presented to the peripheral. The second half is the data phase when data is presented to or received from the peripheral. A Wait state mechanism provides peripherals the option to request external cycles to complete a transaction.

The IPBus Bridge has the unique problem of coordinating the system and peripheral buses. It presents hold-off requests to the system bus pipeline when the peripheral bus can’t keep up, either due to Wait states, or when the phase alignment of the system bus and peripheral bus clocks require it. A transaction abort mechanism is provided to retry a peripheral bus transaction which is unable to complete, because the system bus is being held-off by another device.

4.7.2 Clock Hold-Off

If a system bus device is unable to keep up with the pipeline, the only way to handle it is to stall the pipeline. Stalling provides that device extra system clock cycles, or cycles outside of normal pipeline processing, to catch-up. Each system bus device may have an optional hold-off control output specifically for this purpose.

When a device asserts its hold-off control, the pipeline will be halted in the next cycle. That device will be clocked in the next cycle but any device not having an asserted hold- off control will not be clocked. The system bus devices with a hold-off control are the Data RAM and the IPBus Bridge.

The Data RAM requires one hold-off when an X2 data bus read immediately follows an X1 data bus write. The IPBus Bridge generates hold-off when an IPBB transaction begins out-of-phase with the peripheral bus clock, when a system bus transaction generates multiple IPBus transactions, and when IPBus transactions generate Wait states.

Other system bus devices, including the program RAM, share a general purpose system clock. There is no hold-off control for the general purpose system clock because it never requires extra clocks. The general purpose system clock, however, can be held off by other system bus devices.

4.7.3 Core Stall

The 56852 system bus has one master, the 56800E core. Therefore, it does not use the core stall mechanism.

4.7.4 Wait Request

A Wait Request is a peripheral bus concept. Peripheral bus transactions are all single cycle. If a peripheral can’t respond in one cycle, it asserts a Wait Request output to the Intellectual Properties Bus Bridge (IPBB), thereby causing it to extend the duration of the current transaction into the next peripheral bus cycle. Thus, each Wait state will result in the IPBB generating two additional system bus hold-offs. These Wait states are typically user-configured, utilizing the programming features of the supporting peripherals.

4.7.5 Transaction Abort

A Transaction Abort occurs when a peripheral bus transaction can’t complete because a hold-off request is asserted during the second half (data phase) of the peripheral bus transaction. This hold-off request will inhibit the next clock to the core, thus preventing it from completing the transaction.

The SIM provides an output to the IPBB and to the peripheral bus address decoder, indicating when a system bus hold-off has occurred. In such cycles, the peripheral bus address decoder will deassert all peripheral bus selects. By deasserting the peripheral select during the data phase of a peripheral bus transaction, the peripheral does not see a valid transaction, thereby it is unaffected. By sensing a hold-off occurred during the data phase of a peripheral bus transaction, the IPBB will retry the peripheral bus transaction in the next peripheral bus cycle.

4.7.6 Coordination of Peripheral and System Buses by IPBB

When system bus transactions are directed to the IPBB, the IPBB will generate hold-offs on the system bus as needed to coordinate peripheral and system bus activity. The number of hold-offs is influenced by:

- Phase alignment of the system and peripheral buses
- Number of peripheral bus transactions required to process the system bus transaction
- Number of Wait states requested by the peripheral when processing each of the peripheral bus transactions.

4.7.7 Clock Waveforms

All generated clocks are true for the first half period and false for the second half period. Any mechanism inhibiting a clock, such as hold-off, core stall, and so on, causes the clock to remain low during the entire period.

The CLK_MSTR input can be fed by the:

- PLL output
- Oscillator running with a crystal
- Oscillator input being clocked externally

Clock frequencies follow:

- System bus clock frequency is always CLK_MSTR/2
- Peripheral bus clock frequency is always CLK_MSTR/4
- CLKOUT frequency is always CLK_MSTR/8

4.8 Generated Clocks

A description of the System Integrated Module (SIM) clock signals is delineated in **Table 4-12.**

Table 4-12. SIM Clock Signals

Clock Output	Frequency	Enable Condition	Used By
CLK_SYS_DRAM	CLK_MSTR/2	((~Hold-off) | HOLD_DRAM) and (Run mode)	Data RAM
CLK_SYS_IPBB	CLK_MSTR/2	((~Hold-off) | HOLD_IPBB) and (Run mode)	IPBus Bridge
CLK_SYS_CPUCLK	CLK_MSTR/2	(~c7waitst) and Run mode	Core
CLK_CPU_PCLK	CLK_MSTR/2	(~Stop mode) and ((~$\overline{\text{RST\_CORE}}$) | jhawkcoretap_en | EOnCE ebl) Note: jhawkcoretap_en is resynchronized before use	Core EOnCE clock
CLK_CPU_NCLK	CLK_MSTR/2	(~Stop mode) and ((~$\overline{\text{RST\_CORE}}$) | n1clken)	Core EOnCE clock
CLK_CPU_WCLK	CLK_SCAN	Always Enabled	Core scan clock
CLK_SYS_GENRL	CLK_MSTR/2	(~Hold-off) and (Run mode)	SIM, Program RAM, SBC, SAD, ROM
CLK_SYS_GENRL_INV	CLK_MSTR/2	(~Hold-off) and (Run mode) & (TMODE_BIST)	RAM and ROM BIST
CLK_SYS_CONT	CLK_MSTR/2	Always Enabled	SIM
CLK_PER_CONT	CLK_MSTR/4	~Stop mode	Peripherals
CLK_PER_CONT_INV	CLK_MSTR/4	~Stop mode	EMI
CLK_CLKOUT	CLK_MSTR/8	~CLKOUT Disable	Output pad CLKOUT
PCLK_PHASE	—	Identical to CLK_PER_CONT, but phase shifted to rise earlier	DMA, IPBB
HOLD-OFF	—	HOLD_DRAM | HOLD_IPBB	PAD, IPBB
C7WAITST	—	(Hold-off | CORE_STALL) and $\overline{\text{RST\_CORE}}$	Core

4.9 Generated Resets

The SIM supports four sources of reset.

- Two asynchronous sources are:
  - — External reset pin
  - — Power-On Reset (POR)
- The two synchronous sources are:
  - — Software reset, generated within the SIM itself
  - — COP reset

The reset generation module has two reset detectors:

1. A chip internal reset is detected when any of the sources assert.
2. A POR reset is detected only when the Power-On Reset input asserts and 32-input clocks have been observed.

The detectors assert asynchronously to asynchronous sources and synchronously to synchronous sources. They always deassert synchronously. They remain asserted until the last active reset source deasserts. The chip-internal reset detector output is the primary reset used within the SIM. The software control registers are reset by the POR reset detector.

The SIM generates four reset outputs. All are active low. These all are activated by one of the two detectors but remain asserted for 32-system clock cycles after the detector deasserts. This permits the SIM to generate 32-system clock cycles of continuous clocking to the part while the reset remains asserted. This is required to clear synchronous resets within the core and elsewhere in the part. The $\overline{\text{RST\_CORE}}$, $\overline{\text{RST\_PERIPH}}$. $\overline{\text{RST\_CGM}}$ outputs are activated by the chip-internal reset detector. The $\overline{\text{RST\_CORE}}$ output is used to reset the core. The $\overline{\text{RST\_CGM}}$ is used to reset the CGM module. The $\overline{\text{RST\_PERIPH}}$ reset is used to reset everything else.

JTAG standards require the part to be held in reset during external boundary scan operations. When the BSCAN_EBL input is asserted, all resets used within the SIM and all reset outputs of the SIM will go to their active asserted state. This prevents accidental damage due to random inputs applied during boundary scan testing.

The Software Reset is only operable in the Run mode when the CPU is able to write to the SIM control register to activate the Software Reset.

4.10 Power Mode Controls

The Power Mode Control module controls movement between the three power modes supported by the core:

- Run mode provides full functionality
- Wait mode disables
  - — execution of the core
  - — any unnecessary system clocks
- Stop mode disables
  - — 56800E core
  - — all system clocks
  - — peripheral bus clock

— PLL optionally

— OSC optionally

The time-based clock generated by the oscillator and Clock Generation Module (CGM) are not affected by Low Power modes. Time based functions such as the Computer Operating Properly (COP) module must be individually disabled for maximum low-power effects. Likewise, Power Mode Controls do not affect pull-up/pull-down resistor enabling. Power loss through input and bidirectional I/O cell pull-up/pull-down resistors can be eliminated by disabling the resistor in the software where supported, or in the case of bidirectional I/O, by putting the cell in an output state and avoiding external contention.

When the core executes a Stop or Wait instruction it will wait until any stall or hold-off activity has completed (c7WAITST has deasserted) then assert the p5STOP or p5WAIT SIM input and the SIM will enter the corresponding Low Power mode. The SIM Control register also contains Stop and Wait disable bits. When asserted, these cause the core to ignore Stop and Wait instructions.

Recovery from the Stop or Wait modes automatically reverts to the Run mode if there is a:

- Pending enabled interrupt (INT_PEND input asserts) e.g. Level Sensitive IRQA/IRQB asserts
- Debug mode request from the core due to a JTAG initiated the Debug mode entry request (jtdebreq input asserts)
- Debug mode entry request from the $\overline{\text{DE}}$ input pad ($\overline{\text{DE}}$ asserts)
- COP Time-out

The SIM has special control relationships with both the Oscillator (OSC) module and the Phase Locked Loop (PLL) module, used in the Stop mode. By default, the SIM provides an extremely low power Stop mode (when OMR6_SD set to zero) by shutting down the PLL and, if possible, the oscillator master clock output. Optionally, (when OMR6_SD set to one) the SIM supports fast Stop mode recovery by leaving the PLL and oscillator output stage alone when entering the Stop mode.

Extreme low power Stop mode works as follows. Upon entering the Stop mode, the SIM asserts its PLL_SHUTDOWN output, causing the PLL to be disabled and bypassed. After one cycle, it asserts its OSC_LOPWR output, feeding the LOW_PWR_MODE input of OSC.

When a fast Stop mode recovery is used (i.e. the OMR6_SD bit in the core is set), neither OSC_LOPWR nor PLL_SHUTDOWN will assert during the Stop mode entry. In this case, the Stop mode entry leaves the clock generation system alone. When there is a return to the Run mode, the clock (PLL based or direct) will be just as it was when Stop was entered. This consumes more power, but it avoids the delay associated with restarting the PLL and waiting for it to lock.

Note: The TAP must be reset ($\overline{\text{TRST}}$ set low) prior to the first functional reset of the part. The TAP reset musts be asserted at power-on for the POR reset to work correctly.

The SIM does not automatically restart or select the PLL upon recovery from Low Power mode. This choice is left to the applications software. Refer to the documentation of the oscillator module for details on its Low Power mode input.

Chapter 5
External Memory Interface (EMI)

5.1 Introduction

The External Memory Interface (EMI) provides an interface allowing 56800E core to utilize external asynchronous memory. The EMI for the 56800E core operates from the system bus.

The 56800E core EMI is implemented as a core bus peripheral. Data can be transferred through the EMI to the core directly.

The EMI described in this document is intended to be interfaced to 16-bit wide external memory. External arrays may be implemented either using single 16-bit wide parts or pairs of 8-bit wide memories. An external data space memory interface to the 56800E core accommodating single 8-bit wide external data memories could be implemented (at a substantial performance penalty) with appropriate programming of the CSOR register(s).

5.2 Features

The External Memory Interface supports the following general characteristics:

- Can convert any internal bus memory request to a request for external memory
- Can manage multiple internal bus requests for external memory access
- Has up to four $\overline{\text{CS}n}$ configurable outputs for external device decoding
  - each $\overline{\text{CS}}$ can be configured for Program or Data space
  - each $\overline{\text{CS}}$ can be configured for Read only, Write only, or Read/Write access
  - each $\overline{\text{CS}}$ can be configured for the number of wait states required for device access
  - each $\overline{\text{CS}}$ can be configured for the size and location of its activation
  - each $\overline{\text{CS}}$ is independently configured for setup and hold timing controls for both read and write

5.3 Functional Description

The 56800E core architecture contains three separate buses for access to memory/peripherals. The EMI attaches to all of these buses and provides an interface to external memory over a single external bus. The EMI serializes these internal requests to external memory in a manner avoiding conflicts and contention.

5.3.1 Core Interface Detail

Managing the core access to the external memory consists of four issues: (Please refer to **Figure 5-1.**)

1. Any of the three buses can request external access at any time. This means the EMI can potentially have three requests it must be completed before the core can proceed. The EMI must hold-off further execution of the core until it can serialize the requests over the external bus. This provides *simultaneous* data for all buses to the core for read operations.
2. There may be a mixture of read and write requests on the core buses. For instance, the program memory bus may request a read operation while the primary data bus (XAB1) is requesting a write operation.
3. The primary data bus (XAB1) may request an 8-bit transfer. This request must access the appropriate external byte.
4. The primary data bus (XAB1) may request a 32-bit transfer. This request requires two accesses of the external bus. The EMI must hold-off further core execution until all 32 bits have been transferred. This action may happen in conjunction with item one above.

5.4 Block Diagram

A simplified block diagram illustrating the connections to the EMI is illustrated in **Figure 5-1.** The left side of the figure shows connections to the 56800E core buses and clocks. All available external EMI signals are shown on the right side of the figure. In some cases, pin count restrictions may limit the number of EMI signals brought out of the package.

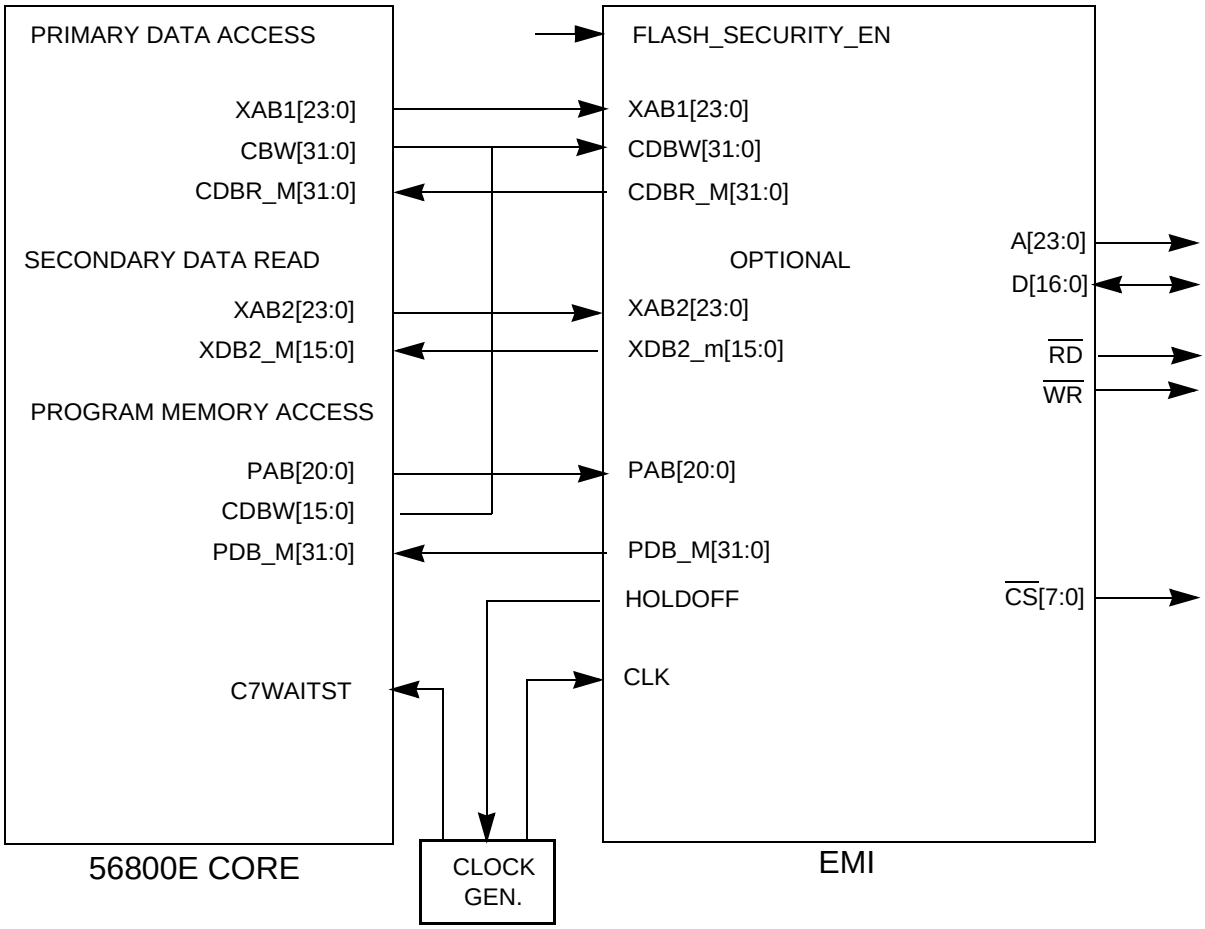


Figure 5-1. EMI Block Diagram

5.5 Module Memory Map

The address of a register is the sum of a base address and an address offset. The base address is defined at the device level. Registers are summarized in **Table 5-1.**

Table 5-1. EMI Module Memory Map (EMI_BASE = $1FFE40)

Address Offset	Register Acronym	Register Name	Chapter Location
Base + $0	CSBAR0	Chip Select Base Address Register 0	Section 5.6.1
Base + $1	CSBAR1	Chip Select Base Address Register 1	
Base + $2	CSBAR2	Chip Select Base Address Register 2	
Base + $3	CSBAR3	Chip Select Base Address Register 3	
Base + $8	CSOR0	Chip Select Option Register 0	Section 5.6.2
Base + $9	CSOR1	Chip Select Option Register 1	
Base + $A	CSOR2	Chip Select Option Register 2	
Base + $B	CSOR3	Chip Select Option Register 3	
Base + $10	CSTC0	Chip Select Timing Control Register 0	Section 5.6.3
Base + $11	CSTC1	Chip Select Timing Control Register 1	
Base + $12	CSTC2	Chip Select Timing Control Register 2	
Base + $13	CSTC3	Chip Select Timing Control Register 3	
Base + $18	BCR	Bus Control Register	Section 5.6.4

Add. Offset	Register Name		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$0	CSBAR0	R	ADR 23	ADR 22	ADR 21	ADR 20	ADR 19	ADR 18	ADR 17	ADR 16	ADR 15	ADR 14	ADR 13	ADR 12	BLKSZ			
		W																
$1	CSBAR1	R	ADR 23	ADR 22	ADR 21	ADR 20	ADR 19	ADR 18	ADR 17	ADR 16	ADR 15	ADR 14	ADR 13	ADR 12	BLKSZ			
		W																
$2	CSBAR2	R	ADR 23	ADR 22	ADR 21	ADR 20	ADR 19	ADR 18	ADR 17	ADR 16	ADR 15	ADR 14	ADR 13	ADR 12	BLKSZ			
		W																
$3	CSBAR3	R	ADR 23	ADR 22	ADR 21	ADR 20	ADR 19	ADR 18	ADR 17	ADR 16	ADR 15	ADR 14	ADR 13	ADR 12	BLKSZ			
		W																
$8	CSOR0	R	RWS					BYTE_EN		R/W		PS/DS		WWS				
		W																
$9	CSOR1	R	RWS					BYTE_EN		R/W		PS/DS		WWS				
		W																
$A	CSOR2	R	RWS					BYTE_EN		R/W		PS/DS		WWS				
		W																
$B	CSOR3	R	RWS					BYTE_EN		R/W		PS/DS		WWS				
		W																
$10	CSTC0	R	WWSS		WWSH		RWSS		RWSH		0	0	0	0	0	MDAR		
		W																
$11	CSTC1	R	WWSS		WWSH		RWSS		RWSH		0	0	0	0	0	MDAR		
		W																
$12	CSTC2	R	WWSS		WWSH		RWSS		RWSH		0	0	0	0	0	MDAR		
		W																
$13	CSTC3	R	WWSS		WWSH		RWSS		RWSH		0	0	0	0	0	MDAR		
		W																
$18	BCR	R	DRV	BMDAR			0	0	BWWS					BRWS				
		W																

R	0	Read as 0
W		Reserved

Figure 5-2. EMI Register Map Summary

5.6 Register Descriptions (EMI_BASE = $1FFE40)

5.6.1 Chip Select Base Address Registers 0–3 (CSBAR0–CSBAR3)

The CSBAR registers are defined in **Figure 5-3.** It determines the active address range of a given $\overline{CS}n$. The Block Size (BLKSZ) field determines the size of the memory map covered by the $\overline{CS}n$. This field also determines which of the address bits to use when specifying the base address of the $\overline{CS}n$. This encoding is detailed in **Table 5-2.** When the active bits match the address and the constraints specified in the CSOR are also met, the $\overline{CS}n$ is asserted.

The chip-select address compare logic uses only the most significant bits to match an address within a block. The value of the base address must be an integer multiple of the block size (i.e., the base address can be at block size boundaries only). For example, for a block size of 64k, the base address can be 64k, 128k, 192k, 256k, 320k, etc.

Note: The default reset value for $\overline{CSn}$ will enable a 32K block of external memory starting at address zero. This may be defined to be something else for a specific chip in which case the chip user manual will detail the specific reset value.

Base + $0 - $3	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	ADR23	ADR22	ADR21	ADR20	ADR19	ADR18	ADR17	ADR16	ADR15	ADR14	ADR13	ADR12	BLKSZ			
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

Figure 5-3. Chip Select Base Address Registers 0–3 (CSBAR0–CSBAR3)

See Programmer's Sheet on Appendix page B-9

Table 5-2. CSBAR Encoding of the BLKSZ Field

BLKSZ	Block Size	Address Lines Compared
0000	4K	X: ADR[23:12], P: ADR[20:12]
0001	8K	X: ADR[23:13], P: ADR[20:13]
0010	16K	X: ADR[23:14], P: ADR[20:14]
0011	32K	X: ADR[23:15], P: ADR[20:15]
0100	64K	X: ADR[23:16], P: ADR [20:16]
0101	128K	X: ADR[23:17], P: ADR[20:17]
0110	256K	X: ADR[23:18], P: ADR[20:18]
0111	512K	X: ADR[23:19], P: ADR [20:19]
1000	1M	X: ADR[23:20], P: ADR[20:20]
1001	2M	X: ADR[23:21]. All program address space decoded.
1010	4M	X: ADR[23:22]. No program address space decoded.
1011	8M	X: ADR[23:23]. No program address space decoded.
1100	16M	All data address space decoded. No program address space decoded.
1101	Reserved	No data address space decoded. No program address space decoded.
1110	Reserved	No data address space decoded. No program address space decoded.
1111	Reserved	No data address space decoded. No program address space decoded.

5.6.2 Chip Select Option Registers 0–3 (CSOR0–CSOR3)

A Chip Select Option Register is required for every chip select. This register specifies the mode of operation of the chip select and the timing requirements of the external memory.

Note: The $\overline{CSn}$ logic can be used to define external memory wait states even if the $\overline{CSn}$ pin is used as GPIO.

Note: The $\overline{CSn}$ output can be disabled by setting either the PS/DS, R/W or BYTE_EN fields to zero.

Base + $8 - $B	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	RWS					BYTE_EN		R/W		PS/DS		WWS				
Write																
Reset	1	0	1	1	1	0	0	0	0	0	0	1	0	1	1	1

Figure 5-4. Chip Select Option Registers 0–3 (CSOR0–CSOR3)

See Programmer's Sheet on Appendix page B-10

5.6.2.1 Read Wait States (RWS)—Bits 15–11

The RWS field specifies the number of additional system clocks, 0-30 (31 is invalid) to delay for read access to the selected memory. The value of RWS should be set as indicated in **Section 5.7.1.**

5.6.2.2 Upper/Lower Byte Option (BYTE_EN)—Bits 10–9

This field specifies whether the memory is 16 bits wide or one byte wide. If the memory is byte wide, the option of upper or lower byte of a 16-bit word is selectable. **Table 5-3** provides the encoding of this field.

Table 5-3. CSOR Encoding BYTE_EN Values

Value	Meaning
00	Disable
01	Lower Byte Enable
10	Upper Byte Enable
11	Both Bytes Enable

5.6.2.3 Read/Write Enable (R/W)—Bits 8–7

This field determines the read/write capabilities of the associated memory as shown in **Table 5-4.**

Table 5-4. CSOR Encoding of Read/Write Values

Value	Meaning
00	Disable
01	Write-Only
10	Read-Only
11	Read / Write

5.6.2.4 Program/Data Space Select (PS/DS)—Bits 6–5

The mapping of a chip select to program and/or data space is shown in **Table 5-5.**

Table 5-5. CSOR Encoding of PS/DS Values

Value	Meaning	
	Flash_Security_Enable = 0	Flash_Security_Enable = 1
00	Disable	Disable
01	DS Only	DS Only
10	PS Only	Disable
11	Both PS and DS	DS Only

5.6.2.5 Write Wait States (WWS)—Bits 4–0

The WWS field specifies the number of additional system clocks 0-30 (31 is invalid) to delay for write access to the selected memory. The value of WWS should be set as indicated in **Section 5.7.2.**

5.6.3 Chip Select Timing Control Registers 0–3 (CSTC0–CSTC3)

A Chip Select Timing Control (CSTC) register is required for every chip select. This register specifies the detailed timing required for accessing devices in the selected memory map. At reset, these registers are configured for minimal timing in the external access waveforms. Therefore, these registers need only be adjusted if required by slower memory/peripheral devices.

Base + $10 - $13	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	WWSS		WWSH		RWSS		RWSH		0	0	0	0	0	MDAR		
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

Figure 5-5. Chip Select Timing Control Registers 0–3 (CSTC0–CSTC3)

See Programmer's Sheet on Appendix page B-11

5.6.3.1 Write Wait States Setup Delay (WWSS)—Bits 15–14

This field affects the write cycle timing diagram, illustrated in **Figure 5-16.** Additional time (clock cycles) is provided between the assertion of $\overline{CSn}$ and address lines and the assertion of $\overline{WR}$. The value of WWSS should be set as indicated in **Section 5.7.2.**

5.6.3.2 Write Wait States Hold Delay (WWSH)—Bits 13–12

This field affects the write cycle timing diagram, illustrated in **Figure 5-17.** The WWSH field specifies the number of additional system clocks to hold the address, data, and $\overline{\text{CS}}n$ signals after the $\overline{\text{WR}}$ signal is deasserted. The value of WWSH should be set as indicated in **Section 5.7.2.**

5.6.3.3 Read Wait States Setup Delay (RWSS)—Bits 11–10

This field affects the read cycle timing diagram, illustrated in **Figure 5-10.** Additional time (clock cycles) is provided between the assertion of $\overline{\text{CS}}n$ and address lines and the assertion of $\overline{\text{RD}}$. The value of RWSS should be set as indicated in **Section 5.7.1.**

5.6.3.4 Read Wait States Hold Delay (RWSH)—Bits 9–8

This field affects the read cycle timing diagram, illustrated in **Figure 5-11.** The RWSH field specifies the number of additional system clocks to hold the address, data, and $\overline{\text{CS}}n$ signals after the $\overline{\text{RD}}$ signal is deasserted. The value of RWSH should be set as indicated in **Section 5.7.1.**

Note: If both, the RWSS and RWSH fields are set to zero the EMI read timing is set for consecutive mode. In this mode the $\overline{\text{RD}}$ signal will remain active during back-to-back reads from the same $\overline{\text{CS}}n$ controlled memory space.

5.6.3.5 Reserved—Bits 7–3

This bit field is reserved or not implemented. It is read as 0 and cannot be modified by writing.

5.6.3.6 Minimal Delay After Read (MDAR)—Bits 2–0

This field specifies the number of system clocks to delay between reading from memory in a $\overline{\text{CS}}n$ controlled space and reading from another device. Since a write to the device implies activating the controller on the bus, this is also considered a read from another device.

Figure 5-6 illustrates the timing issue requiring the introduction of the MDAR field. In this diagram, $\overline{\text{CS1}}$ is assumed to operate a slow flash memory in P-space while $\overline{\text{CS2}}$ is operating a faster RAM in X-space. In some bus contention cases, it is possible to encounter data integrity problems where the contention is occurring at the time the data bus is sampled.

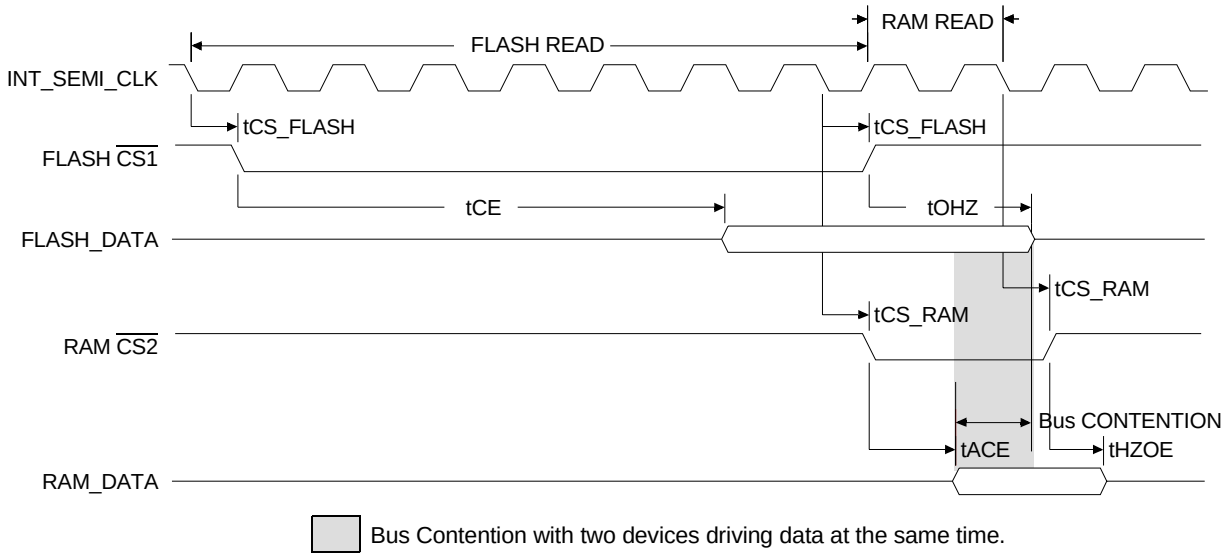


Figure 5-6. Data Bus Contention Timing Requiring MDAR Field Assertion

5.6.4 Bus Control Register (BCR)

The BCR register defines the default read timing for external memory accesses to addresses not covered by the $\overline{CS}$/CSOR/CSTC registers. The timing specified by the BCR register applies to both program and data space accesses because the PS and DS control signals are not directly available on the chip pinouts.

Note: Any of the $\overline{CSn}$ signals can be configured to mirror the $\overline{PS}$ and/or $\overline{DS}$ function, but then the associated $\overline{CSn}$ configuration registers control the timing.

Base + $18	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	DRV	BMDAR			0	0	BWWS					BRWS				
Write																
Reset	0	0	0	0	0	0	0	0	0	1	1	1	1	0	1	1

Figure 5-7. Bus Control Register (BCR)

See Programmer's Sheet on Appendix page B-12

5.6.4.1 Drive (DRV)—Bit 15

The Drive (DRV) control bit is used to specify what occurs on the external memory port pins when no external access is performed (whether the pins remain driven or are placed in tri-state). **Table 5-6** summarizes the action of the EMI when the DRV bit is cleared or is set. DRV bit is cleared on hardware reset, but should be set in most customer applications.

Table 5-6. Operation with DRV

800E Core Operating State	DRV	Pins		
		A23:A0	$\overline{RD}$, $\overline{WR}$, $\overline{CSn}$	D15:D0
EMI is Between External Memory Accesses	0	Tri-stated	Tri-stated	Tri-stated
Reset Mode		Tri-stated	Pulled High Internally	Tri-stated
EMI is Between External Memory Accesses	1	Driven	Driven ($\overline{RD}$, $\overline{WR}$, $\overline{CSn}$ are Deasserted)	Tri-stated
Reset Mode		Tri-stated	Pulled High Internally	Tri-stated

5.6.4.2 Base Minimal Delay After Read (BMDAR)—Bits 14–12

This bit field specifies the number of system clocks to delay after reading from memory *not* in $\overline{CS}$ controlled space. Since a write to the device implies activating the controller on the bus, this is also considered a read from another device, therefore activating the BMDAR timing control. Please see the description of the MDAR field of the CSTC registers for a discussion of the function of this control.

5.6.4.3 Reserved—Bits 11–10

This bit field is reserved or not implemented. It is read as 0 and cannot be modified by writing.

5.6.4.4 Base Write Wait States (BWWS)—Bits 9–5

This bit field specifies the number of additional system clocks 0-30 (31 is invalid) to delay for write access to the selected memory when the memory address does *not* fall within $\overline{CS}$ controlled range. The value of BWWS should be set as indicated in **Section 5.7.**

5.6.4.5 Base Read Wait States (BRWS)—Bits 4–0

This bit field specifies the number of additional system clocks 0-30 (31 is invalid) to delay for read access to the selected memory when the memory address does *not* fall within $\overline{CS}$ controlled range. The value of BRWS should be set as indicated in **Section 5.7.**

5.7 Timing Specifications

5.7.1 Read Timing

5.7.1.1 Consecutive Mode Operation

Figure 5-8 illustrates the read timing for external memory access**.** For comparison, a single read cycle is illustrated followed by a null cycle and then a back-to-back read.

Figure 5-8 assumes zero wait states are required for the access. **Figure 5-9** illustrates a timing diagram with one wait state added.

There are two read setup timing parameters for each read cycle. The core will latch the data on the rising edge of the internal clock while t_{RSD} indicates the core setup time. The external timing of the address and controls is adjusted so they may be changing at this time. Therefore, a data latch is introduced to capture the data (at the pin) a quarter clock earlier, on the rising edge of the internal delayed clock. The setup time required for this latch is illustrated by t_{RSDP} in the diagrams. For slow clock speeds, t_{RSDP} is more critical, while t_{RSD} may be harder to meet for faster clock rates.

Note: During back-to-back reads, $\overline{RD}$ remains low to provide the fastest read cycle time.

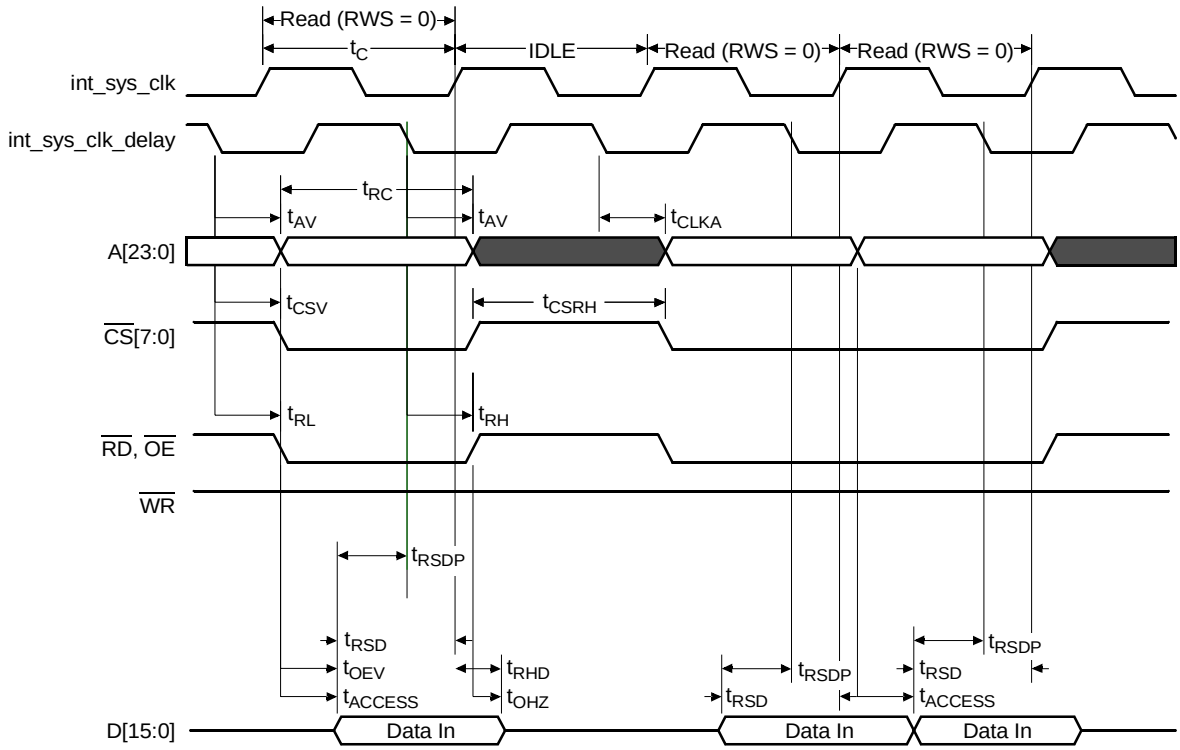


Figure 5-8. External Read Cycle with Clock and RWS = 0

Note: INT_SYS_CLK is the internal system clock from which everything is referenced.

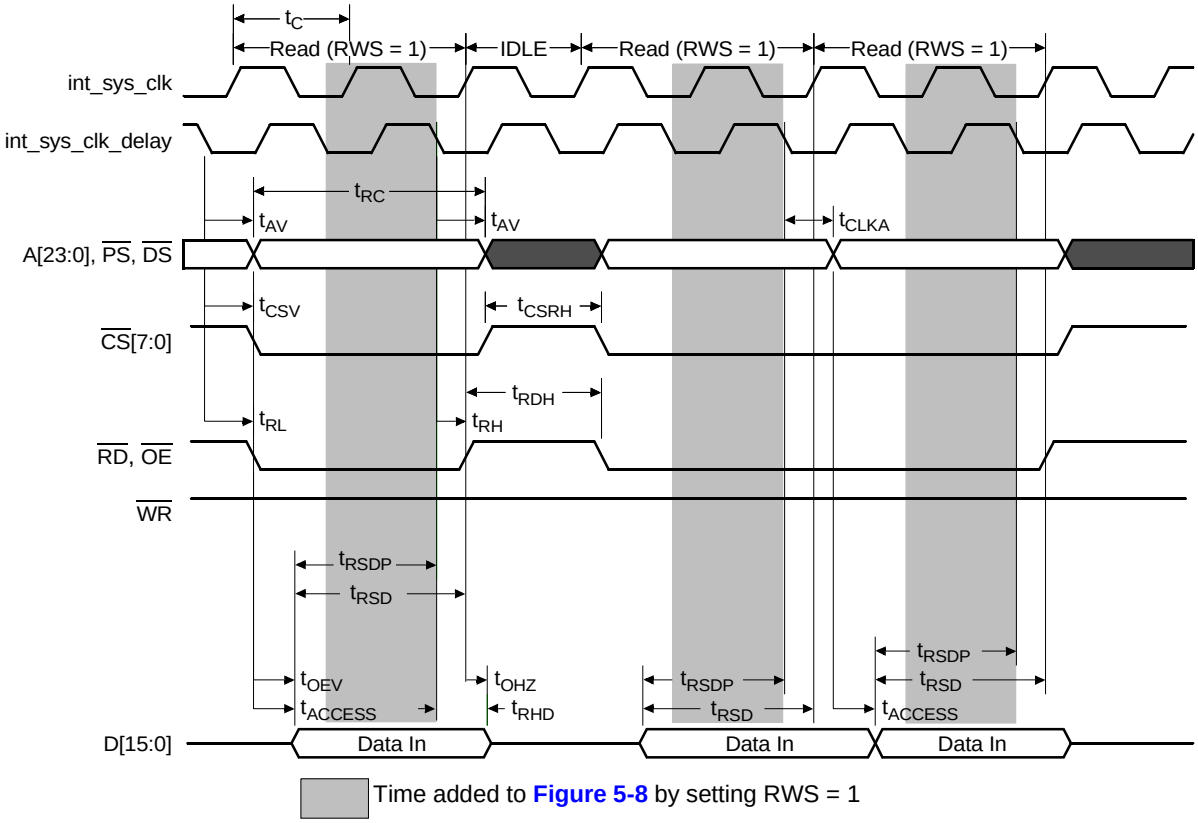


Figure 5-9. External Read Cycle with RWS = 1, RWSH = 0 and RWSS = 0

5.7.1.2 Read Setup and Hold Timing

Although most memory devices can perform consecutive reads by holding the $\overline{CSn}$ and $\overline{RD}(\overline{OE})$ signals in the active state and changing the address, there are peripheral devices that require $\overline{RD}(\overline{OE})$ to transition to the inactive state between reads of certain registers. This timing can be accommodated with the Read Setup (RWSS) and/or Read Hold (RWSH) control fields illustrated in **Figure 5-10** and **Figure 5-11.**

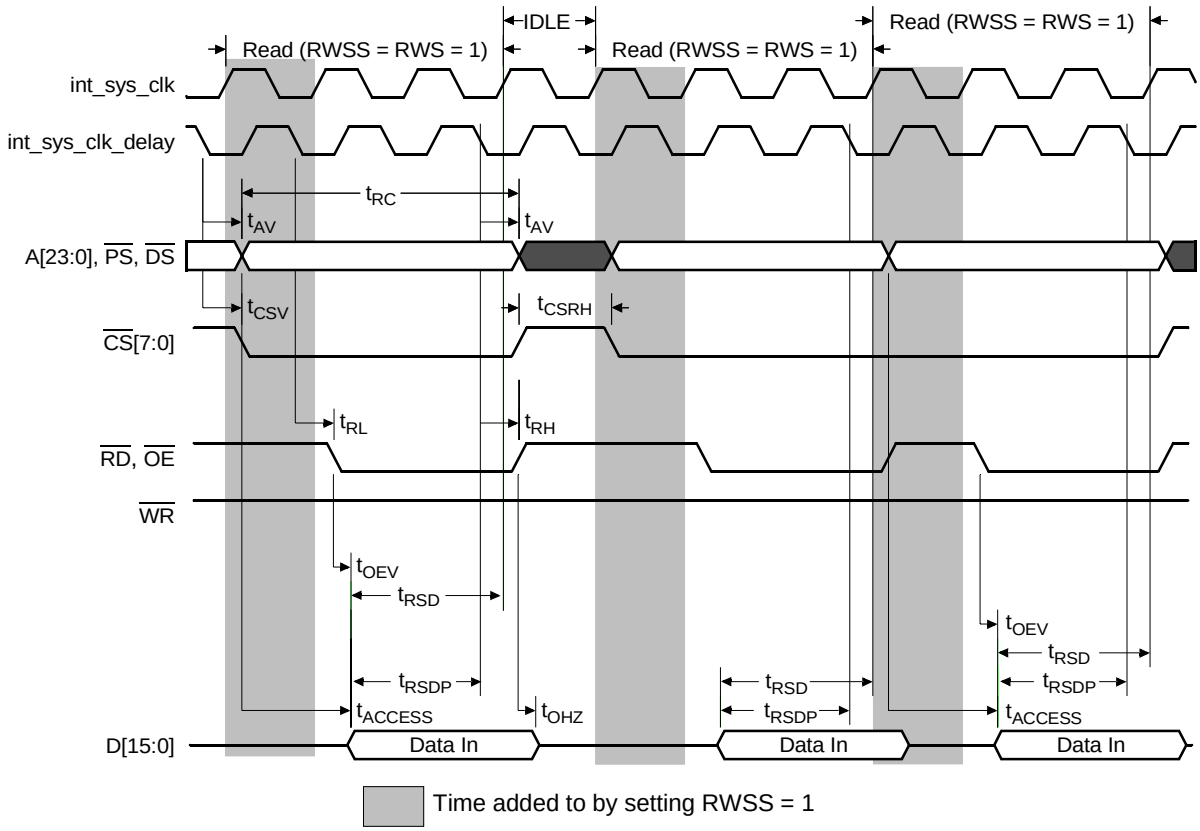


Figure 5-10. External Read Cycle with RWSS = RWS = 1, and RWSH = 0

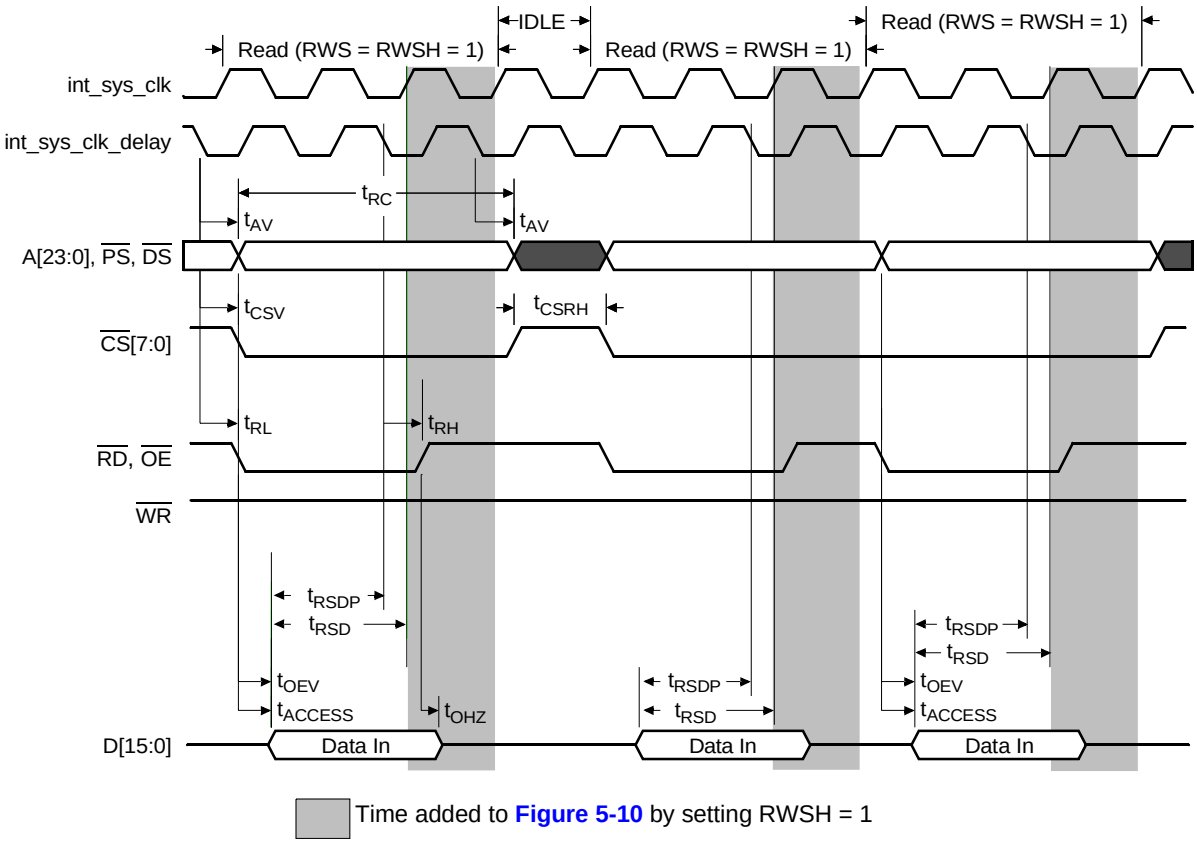


Figure 5-11. External Read Cycle RWS = RWSH = 1 and RWSS = 0

5.7.2 Write Timing

Figure 5-12 shows the write timing for external memory access**.** For comparison, a single write cycle is shown followed by a null cycle and then a back-to-back write.This figure assumes zero wait states are required for the access.

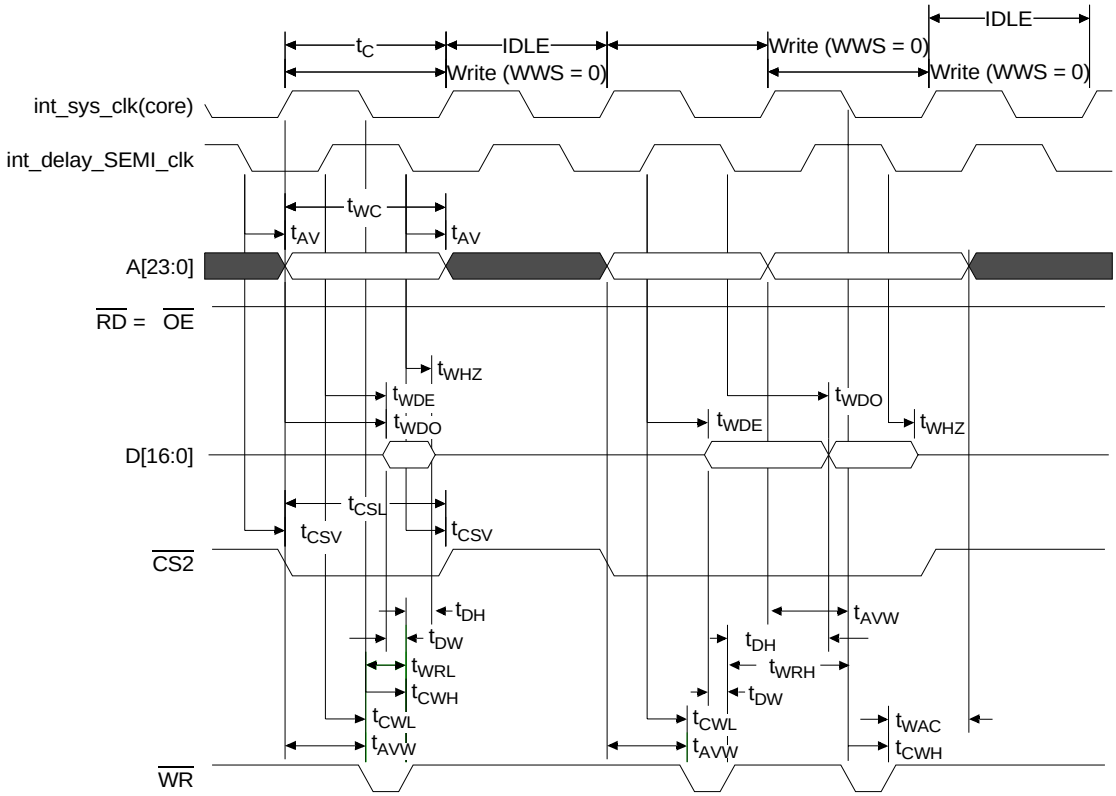


Figure 5-12. External Write Cycle

Note: When WWS = 0 the timing of the $\overline{WR}$ strobe is generated from different clock edges than when it is set to some other value. This change in timing allows the possibility of single cycle write operation, but reduces the pulse width of $\overline{WR}$ to one quarter clock. This may make it difficult to meet write timing requirements for most devices when operating at normal clock rates.

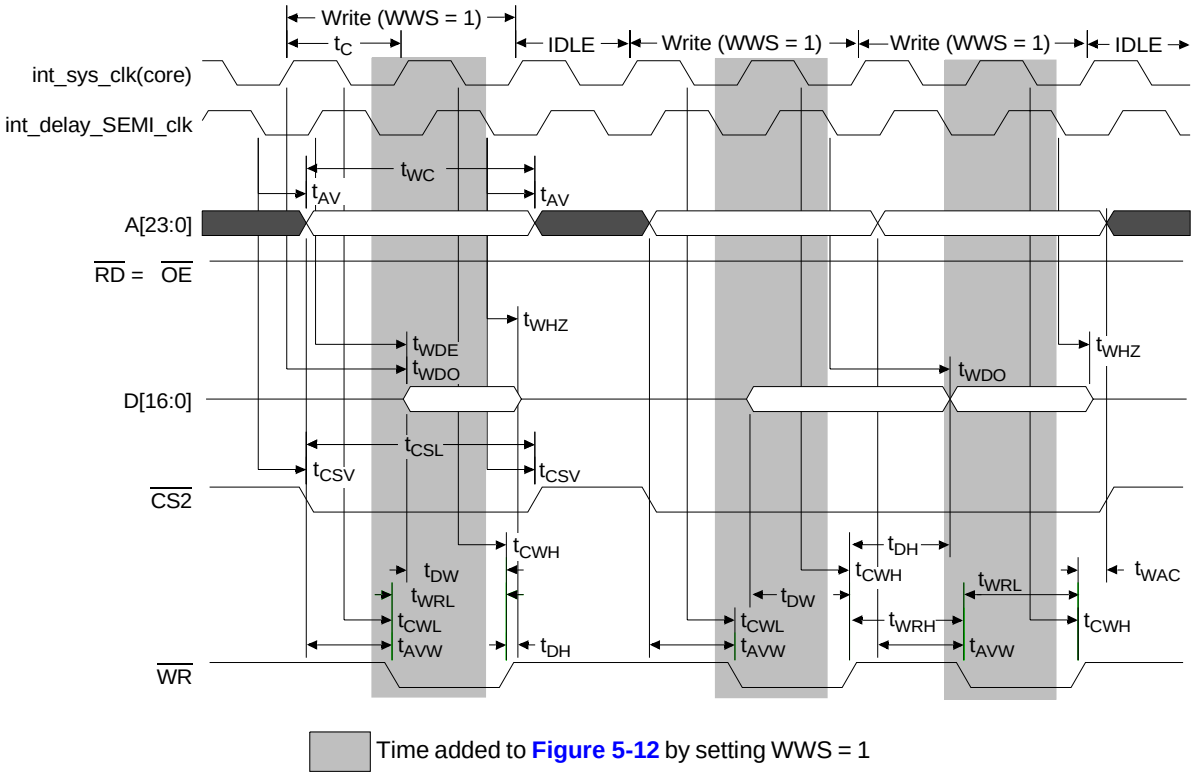


Figure 5-13. External Write Cycle with WWS = 1, WWSH = 0, and WWSS = 0

5.7.2.1 Write Setup and Hold Timing

Since the timing of the strobes is different when WWS = 0 than it is when WWS > 0, two sets of timing diagrams are illustrated in **Figure 5-14, Figure 5-15, Figure 5-16,** and **Figure 5-17.**

5.7.2.2 WWS = 0

Although most memory devices require a zero setup and hold time, there are some peripheral devices where a setup/hold time is required. The WWSS and WWSH field of the CSTC register provides the ability to allow for a write setup and/or hold time requirement as shown in **Figure 5-14** and **Figure 5-15.**

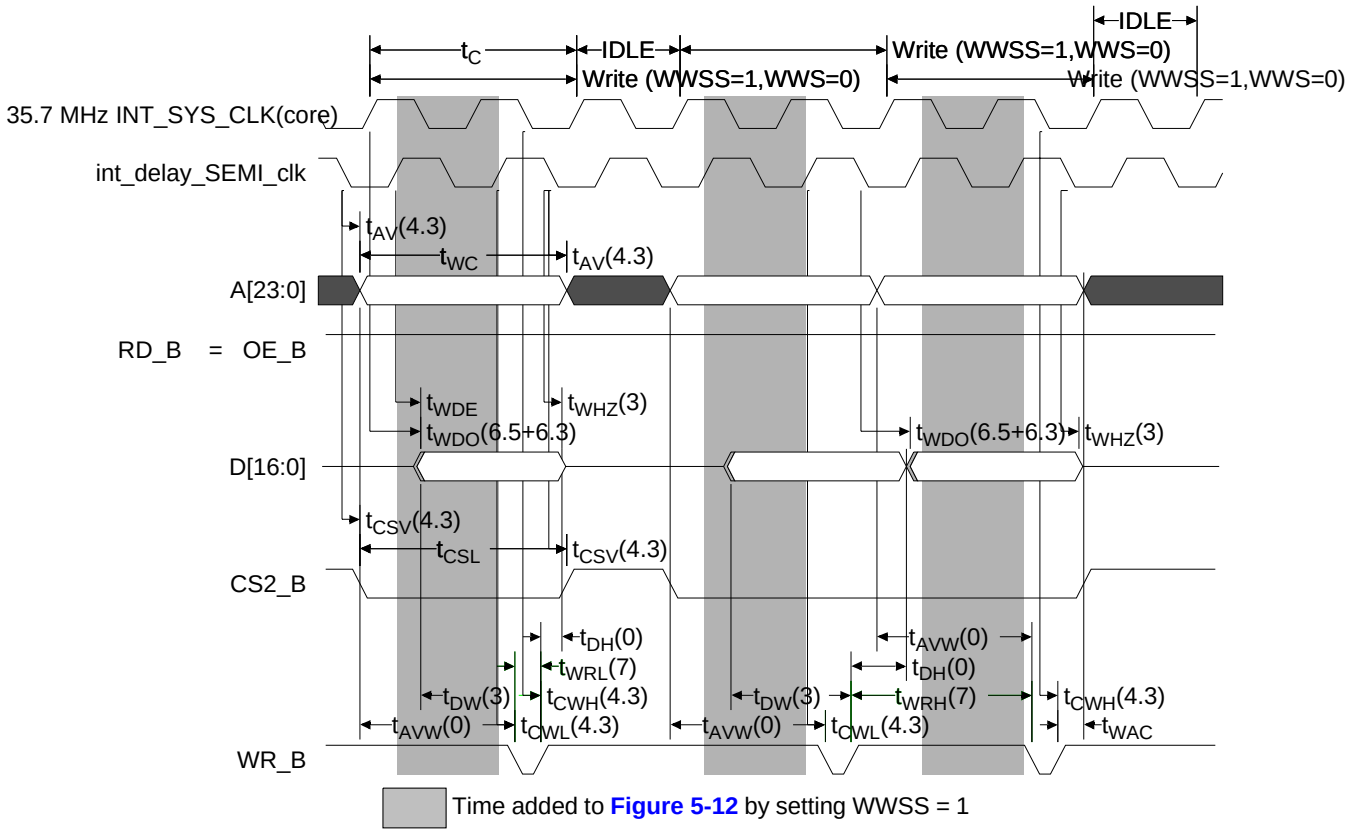


Figure 5-14. External Write Cycle with WWSS = 1, WWS = 0 and WWSH = 0

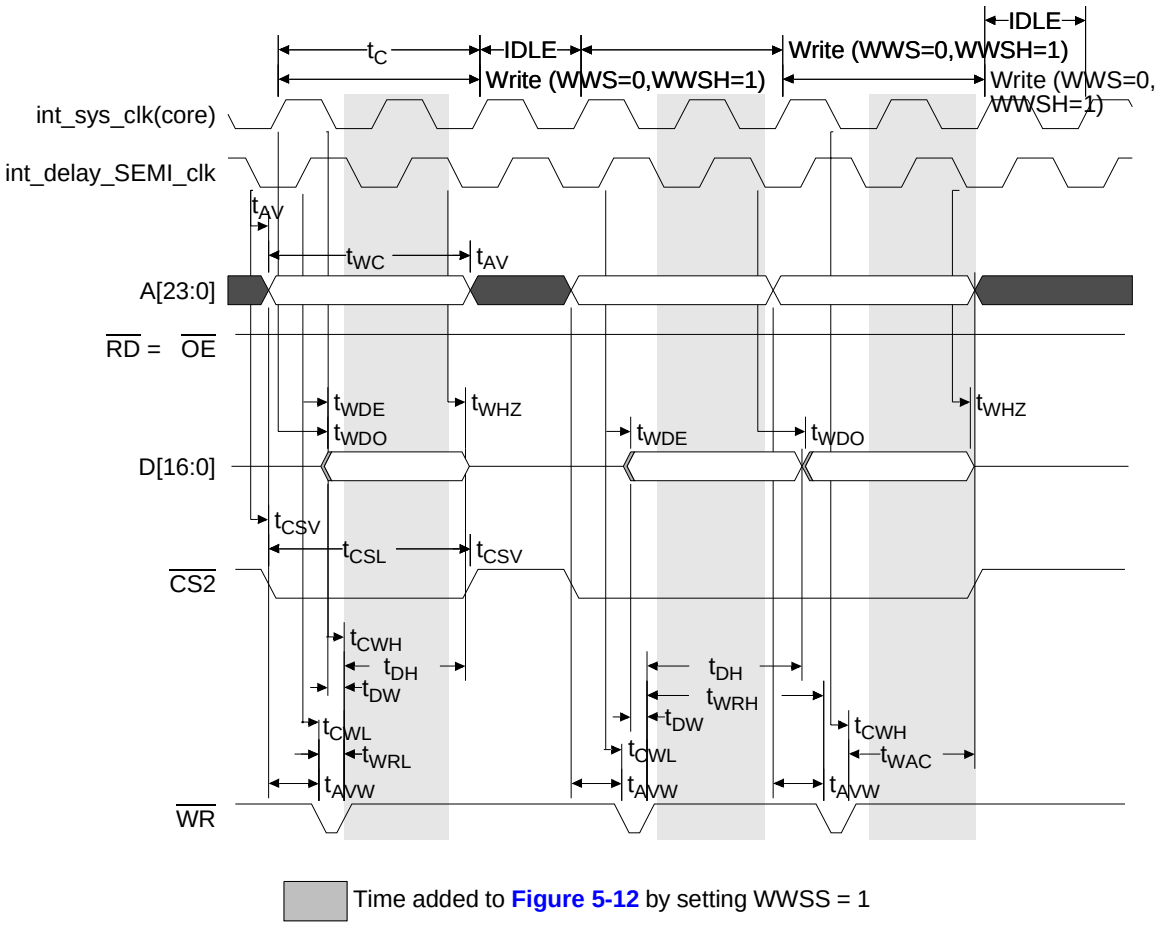


Figure 5-15. External Write Cycle with WWS = 0, WWSH = 1, WWSS = 0

5.7.2.3 WWS > 0

Although most memory devices require a zero setup and hold time, there are some peripheral devices where a setup/hold time is required. The WWSS and WWSH field of the CSTC register provides the ability to allow for a write setup and/or hold time requirement as shown in **Figure 5-16** and **Figure 5-17** respectively.

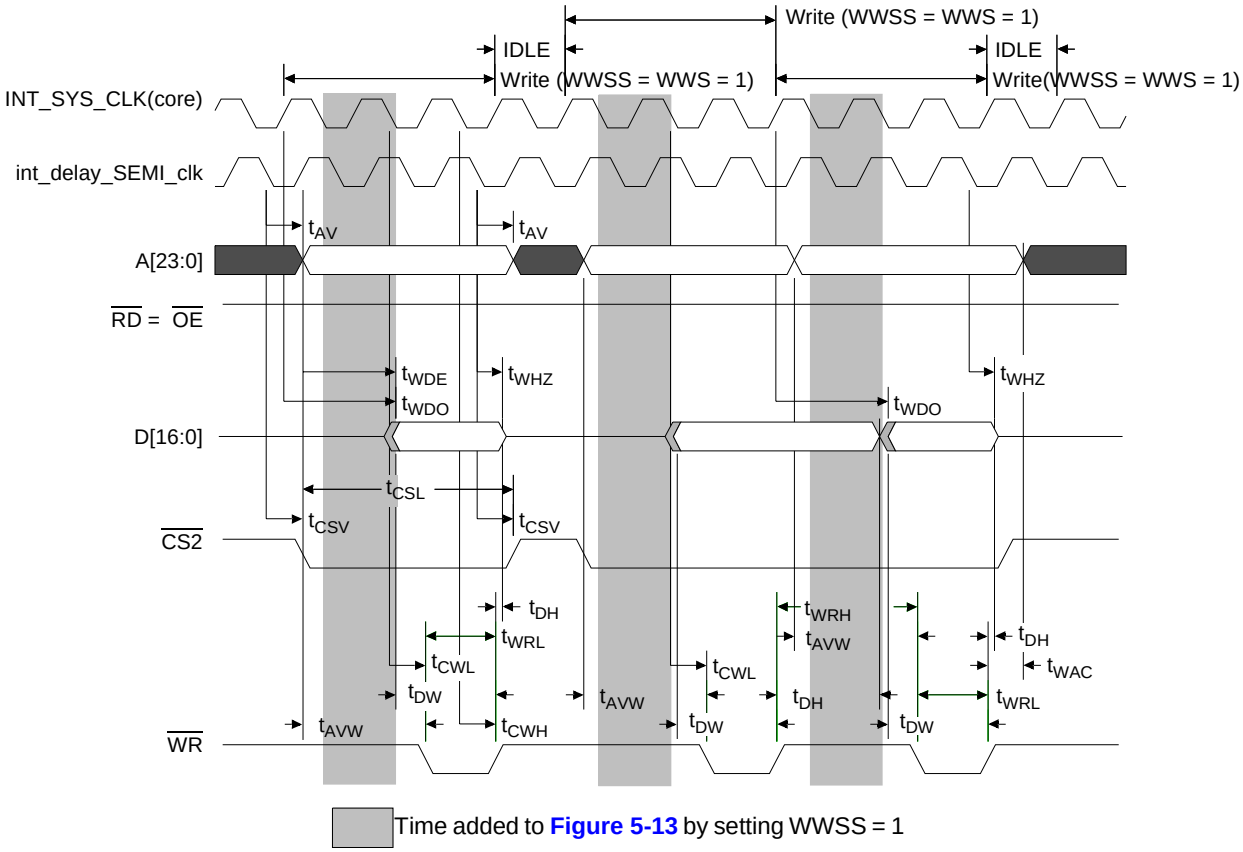


Figure 5-16. External Write Cycle with WWSS = WWS = 1 and WWSH = 0

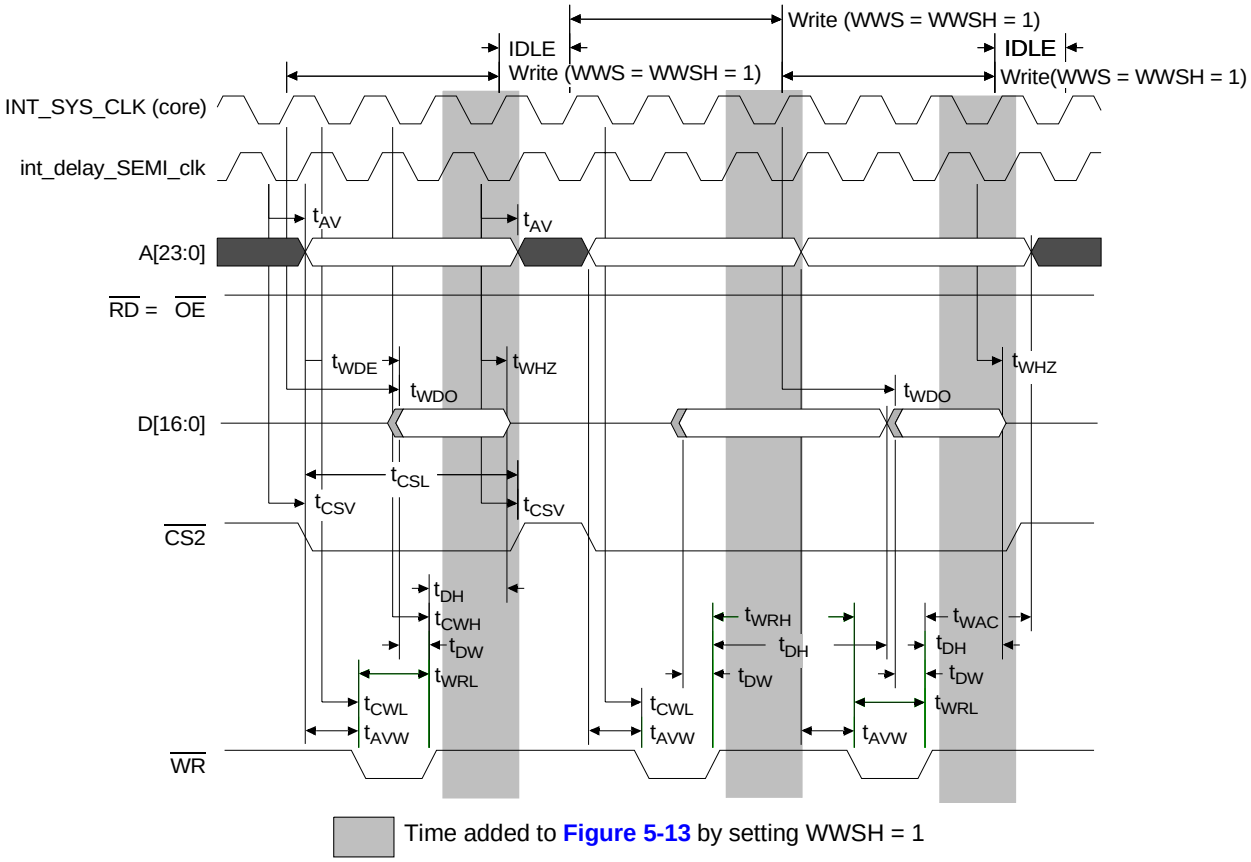


Figure 5-17. External Write Cycle with WWS = WWSH = 1 (WWSS = 0)

5.8 Clocks

The EMI operates from clocks internal to the chip and does not require/provide clocks external to the chip.

5.9 Interrupts

There are no interrupts generated by this module.

5.10 Resets

All reset types are equivalent for the EMI and therefore have the same effect. The EMI outputs during reset are controlled by the DRV bit of the BCR. During reset this bit is set to zero. Therefore, **Table 5-6** defines the reset state of all EMI pins.

Chapter 6
On-Chip Clock Synthesis (OCCS)

6.1 Introduction

The On-Chip Clock Synthesis (OCCS) module allows product design using an inexpensive 4MHz crystal or an external clock source to run the 56852 at any frequency from zero to 120MHz. The OCCS module is comprised of two major blocks: the Oscillator (OSC), and the PLL/CGM (analog - Phase Locked Loop/digital - Clock Generation Module (CGM)). The OSC output clocks feed the PLL/CGM block. The PLL/CGM generates a time clock for Computer Operating Properly (COP) timer use. The PLL/CGM also generates a master clock consumed by the System Integration Module (SIM). The SIM generates derivative clocks for consumption by the core logic and IPBus peripherals.

The SIM divides the MSTR_CLK (typically 240MHz) by two to create the core clock (typically 120MHz) and divides by four to create the IPBUS_CLK (typically 60MHz). All peripherals on the 56852 run off the IPBus clock frequency. The COP and Time-of-Day (TOD) peripherals also consumes the much lower frequency TIME_CLK (typically 31.25KHz).

The PLL may be used to generate a high frequency clock from the low-frequency crystal-referenced (or external clock driven) OSC circuit. The PLL provides an exact integer multiple of the oscillator's output Reference Frequency (Fref). The frequency multiplication is in the range of 20 to 120.

The CGM controls the PLL's output frequency. The CGM also selects between the PLL (PLL_OUT) and OSC (Fref) as potential master clock sources and routes the selection to the SIM. The CGM also contains circuitry to detect if the PLL is unlocked and generates an interrupt signal for the condition.

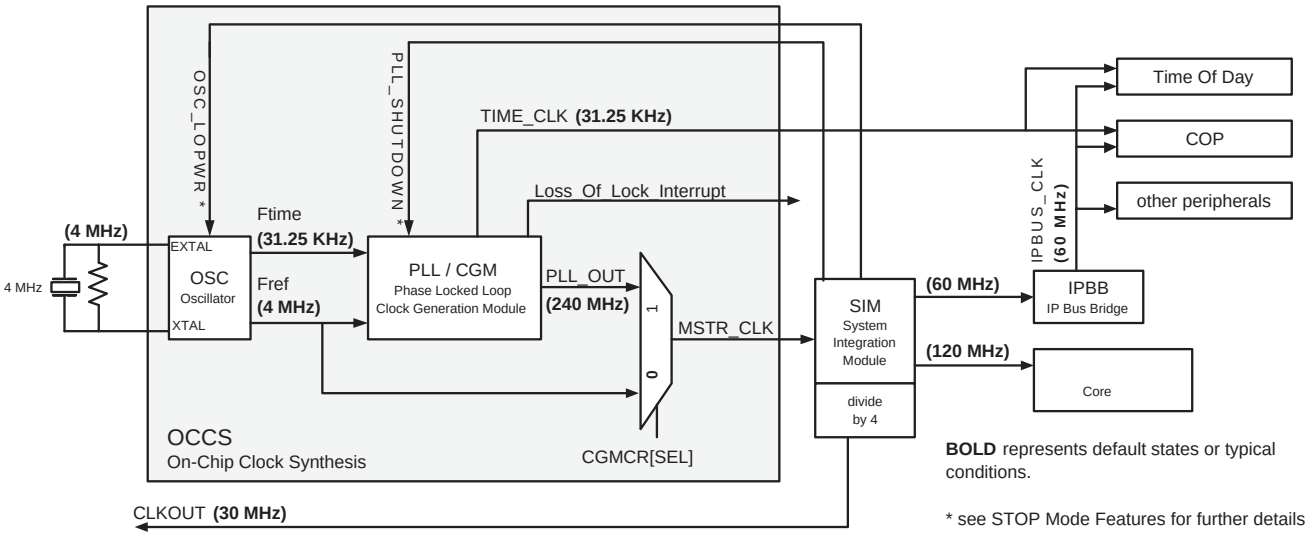


Figure 6-1. OCCS Integration Overview

Out of reset, the CGMCR[SEL] control bit is zero, selecting the Fref path as the source of MSTR_CLK. The core will proceed to execute code using a clock divided down from the oscillator's Fref output. The core will run at Fref/2 and the IPBUS_CLK will run at Fref/4. Among the first things applications typically do is turn on the PLL, wait for lock indication and set CGMCR[SEL] to one, enabling high speed operation.

6.1.1 OCCS Features

- OSC connects to external crystals in the range of 2 to 4MHz
- OSC can optionally accept an external active clock (0 to 240MHz)
- PLL generates any integer multiple frequency, allowing DC to 120MHZ execution
- CGM provides glitch-free transition between OSC and PLL clock sources
- CGM provides digital loss of lock detection
- Ultra Low Power modes are available while COP timer and TOD are kept alive

6.2 OSC (Oscillator) Circuit Detail

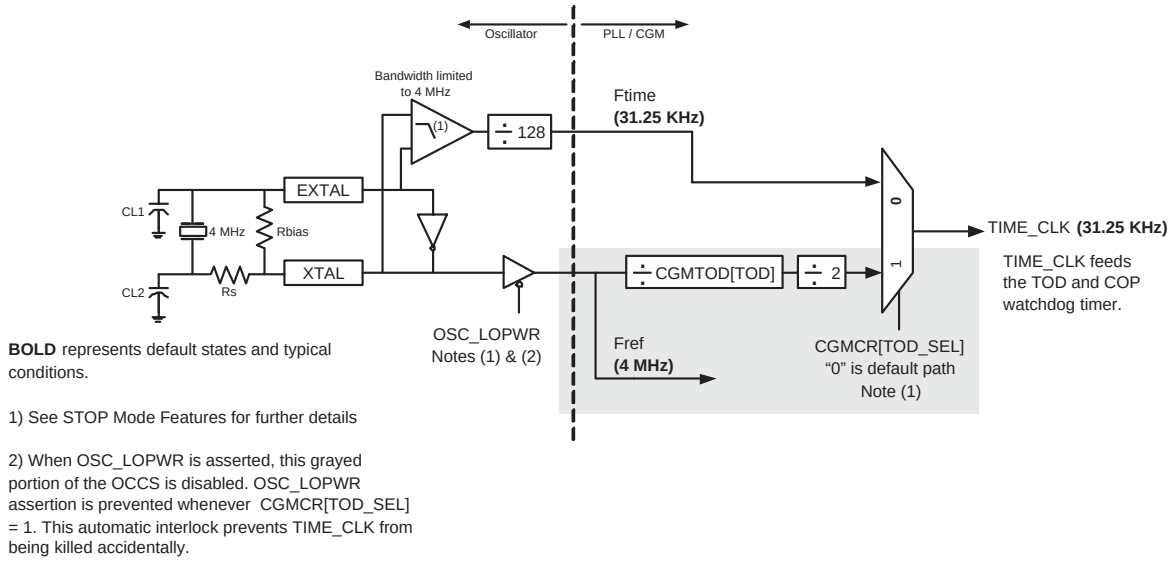


Figure 6-2. OSC Supplying Clocks to PLL/CGM

A typical connection for the OSC module is shown above. The weak differential signal coming in directly from EXTAL/XTAL pin pair is routed to a very low power differential amplifier. Because the amplifier is so low in power, it has a usable bandwidth limit somewhat above just 4MHz. The resulting clock frequency is divided down by a fixed value of 128 to yield a 31.25KHz clock. Out of reset, the register CGMCR[TOD_SEL] is zero, so this is the path selected through the mux to create the TIME_CLK used by the COP and TOD. If the signal present on XTAL is above 4MHz (e.g. driven by an external active clock) then it is necessary to set CGMCR[TOD_SEL] to 1.

The signal from XTAL is buffered up (becoming Fref) and is consumed everywhere else.

6.2.1 Using an External Crystal

The figure below shows the typical application details for using an external crystal. A 4MHz, AT cut, parallel resonant crystal is mounted across XTAL and EXTAL pins. A one Mohm bias resistor is paralleled to that connection. The default path for TIME_CLK generation (the differential amplifier path) is recommended; therefore CGMCR[TOD] register setting is a don't care. Please see **Section 6.2.4** for further details.

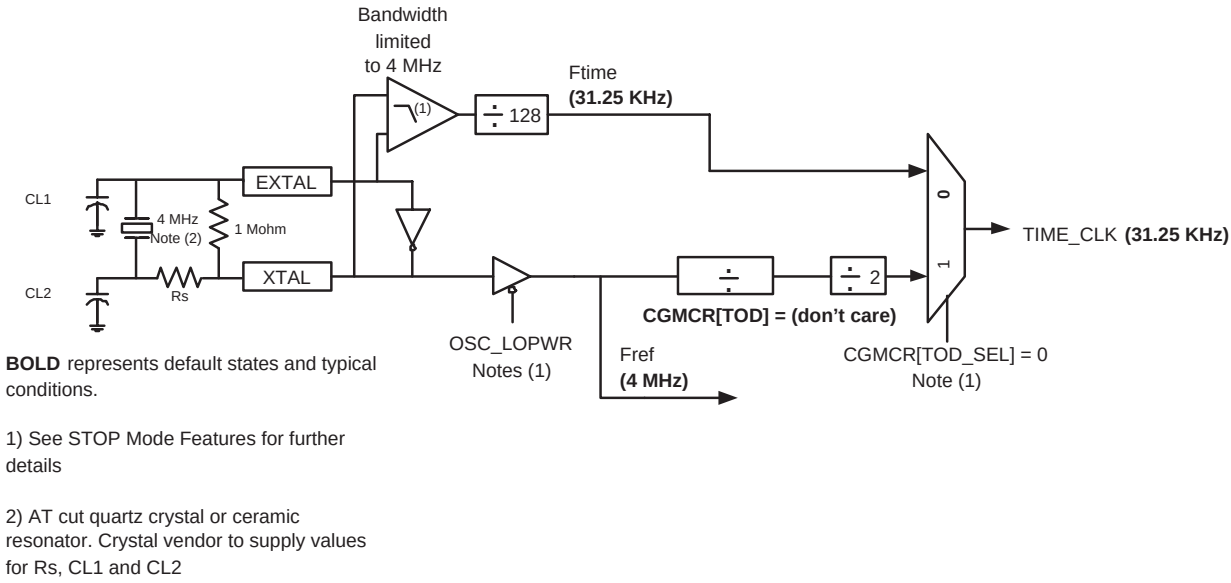


Figure 6-3. Using an External Crystal

The values of Rs, CL1 and CL2 are determined with assistance of your crystal manufacturer. In general, CL1 and CL2 are used to pull the crystal to the intended frequency and establish the Equivalent Series Resistance (ESR). Rs is used to kill off some of the inverter's gain (by an amount appropriate for the resulting ESR).

Note: The CGMCR register's TOD_SEL field may be set to either 0 or 1. The recommended setting of 0 allows very low power operation when executing a STOP instruction.

6.2.2 Using an External Active Clock Source Below 4MHz

When using an external active clock source of a frequency less then or equal to 4MHz then the connections shown below are recommended. Here the EXTAL pin is biased to 1.65V and XTAL is driven with a 0 to 3.3V square wave clock signal. The TIME_CLK source path is the same as above, using the fixed divide by 128 block and channel zero of the mux.

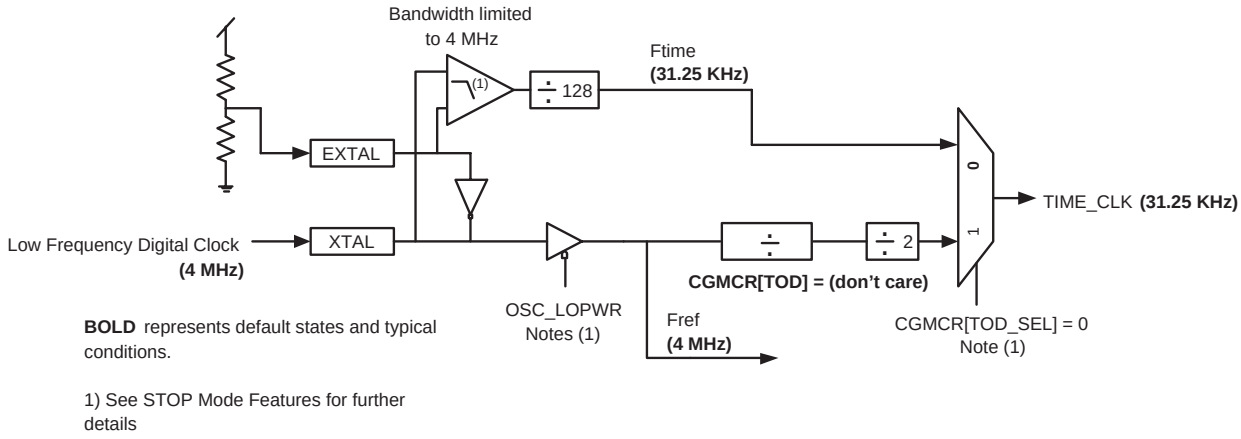


Figure 6-4. Using an External Active *Low* Frequency Clock, < 4MHz

Note: The CGMCR register's TOD_SEL field may be set to either 0 or 1. The recommended setting of 0 allows very low power operation when executing a STOP instruction. If, however, a setting of 1 is used, then EXTAL can be tied to ground, to mid-rail (as shown), or high. If TOD_SEL is set to 1, then the optimal connection of EXTAL is to ground.

6.2.3 Using an External Active Clock Source Above 4MHz

When using an external active clock source that is of a higher frequency than 4MHz (up to 240MHz is allowable) the settings detailed below should be used.

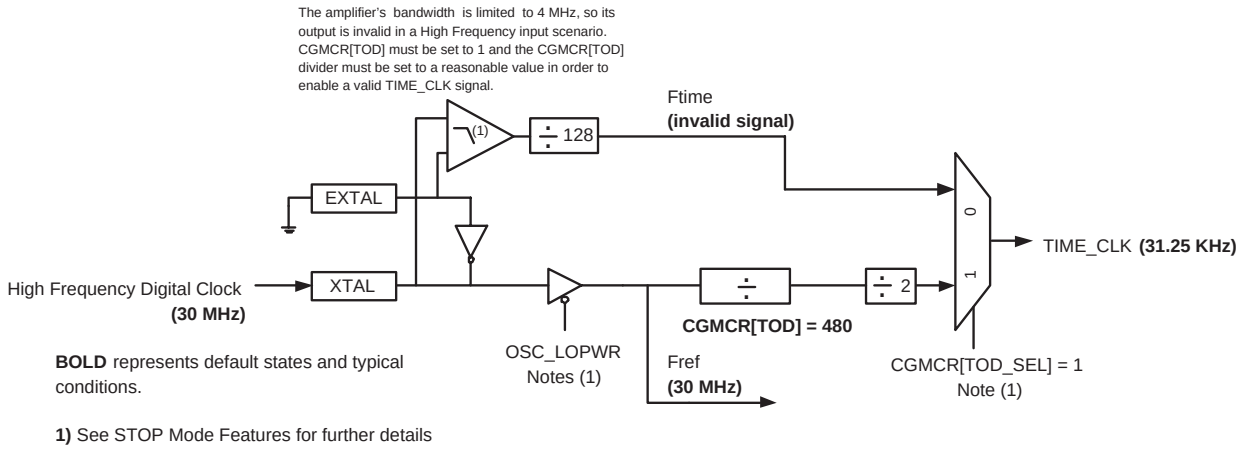

The amplifier's bandwidth is limited to 4 MHz, so its output is invalid in a High Frequency input scenario. CGMCR[TOD] must be set to 1 and the CGMCR[TOD] divider must be set to a reasonable value in order to enable a valid TIME_CLK signal.
Ftime
(invalid signal)
(1)
÷ 128
EXTAL
XTAL
High Frequency Digital Clock
(30 MHz)
÷
÷ 2
0
1
TIME_CLK (31.25 KHz)
CGMCR[TOD] = 480
OSC_LOPWR
Notes (1)
Fref
(30 MHz)
CGMCR[TOD_SEL] = 1
Note (1)
BOLD represents default states and typical conditions.
1) See STOP Mode Features for further details

Figure 6-5. Using an External Active *High* Frequency Clock, > 4MHz

Since the differential amplifier is band limited to just over 4MHz, in this example the default TIME_CLK path's divide by 128 counter will no longer have an adequate signal for proper operation. Instead, the user programmable divide by circuit should be used. This requires correct setting of both the CGMCR[TOD] and [TOD_SEL] register fields illustrated in the figure.

In this particular example, the externally applied clock, and hence Fref are running at 30 MHz. This requires TOD_SEL be set to 1 and the TOD register set to 480. The input frequency of 30MHz divided down by 480 and then again by a fixed value of two yields the desired 31.25KHz TIME_CLK frequency.

Note: With the CGMCR register's TOD_SEL field set to 1, EXTAL can be tied to ground (as shown), to mid-rail, or high. The optimal connection of EXTAL is to ground.

6.2.4 STOP Mode Features

In an attempt to conserve power, applications may power the device down by executing STOP or WAIT instructions. The 56852 OCCS module supports three variants of STOP mode processing.

1. Case where CGMCR[TOD_SEL] = 0

A STOP instruction will result in the MSTR_CLK clock source being forced back to Fref and the PLL being powered down (PLL_SHUTDOWN asserts. If CGMCR[TOD_SEL] is 0, then OSC_LOWPWR will assert, bringing the OSC module into its lowest power alive state. Only the inverter, differential amplifier and the fixed divide by 128 block remain enabled, but that is enough to keep TIME_CLK and the associated COP counter alive and running. Fref is held quiescent.

When waking up from this *deep stop*, the PLL will need to be re-started, lock status re-queried and the PLL output re-selected to source MSTR_CLK.

2. Case where CGMCR[TOD_SEL] =1

A STOP instruction will result in the MSTR_CLK clock source being forced back to Fref and the PLL being powered down (PLL_SHUTDOWN asserts). If CGMCR[TOD_SEL] is 1 when the STOP instruction is executed, then the SIM *will not* assert OSC_LOWPWR for in doing so, the TIME_CLK (and COP) would be killed. This is usually an undesirable situation from an applications perspective.

3. Fast STOP Recovery

A *Fast STOP Recovery* is available in which *neither* the OSC_LOWPWR or PLL_SHUTDOWN signal are asserted. As such, no time is required to re-start the PLL, but it comes at the cost of increased power consumption by the PLL during STOP. Fast Stop Recovery is available by setting the OMR register's bit 6 to 1.

For further details on STOP and Fast STOP Recovery, please see **Section 4.10,** Power Mode Controls.

6.3 Phase Locked Loop (PLL) Circuit Detail

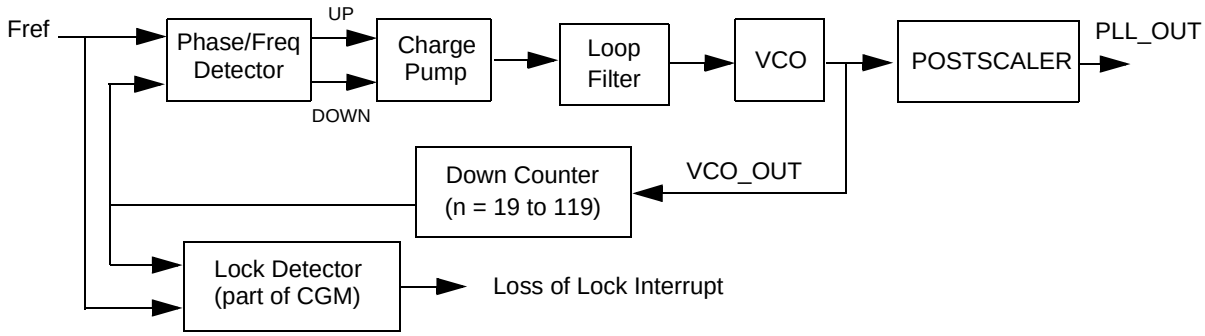


Figure 6-6. PLL Block Diagram

6.3.1 Phase Frequency Detector

The Phase Frequency Detector (PFD) compares the clock signal from the feedback divider to the input clock. When the input clock comes before the feedback clock the PFD generates a *down* pulse signal. The down pulse signal continues until the feedback clock signal arrives. If the feedback clock arrives at the PFD before the input clock, the PFD generates an *up* pulse, continuing until the input clock signal arrives.

6.3.2 Charge Pump

The Charge Pump draws charge into or out of the Loop Filter depending upon the signals from the Phase Frequency Detector. As charge is added to the Loop Filter the Voltage Controlled Oscillator (VCO) control voltage increases. As charge is pulled out of the Loop Filter, the VCO control voltage decreases.

6.3.3 Loop Filter

The Loop Filter produces a voltage proportional to the amount of charge pumped into or out of the Loop Filter by the charge pump. The Loop Filter is a single pole RC filter.

6.3.4 Voltage Controlled Oscillator

The Voltage Controlled Oscillator (VCO) produces a frequency inversely proportional to the value of the control voltage signal coming out of the Loop Filter. The VCO gain is approximately 109MHz/Volt. The VCO has a frequency range of 80MHz to 380MHz with a center frequency of 240MHz.

6.3.5 Down Counter

The Down Counter is a programmable divide by *n* counter where the divide integer *n* is user-set to develop the PLL output frequency of interest. By presenting only one return pulse out of *n* input pulses to the return clock of the phase frequency detector, the PFD will drive the charge pump to raise the VCO frequency until the Down Counter return signal is in frequency and phase lock with the input clock signal. The output of the VCO will, therefore, be *n* times the frequency of the input clock signal. The value of *n* has a valid range of 19 to 119. The selected value of *n* depends upon the desired VCO output frequency and the input clock frequency (Fref). For the 2MHz input crystal the valid range of *n* will range from 39 to 119, producing a VCO frequency output of 80MHz to 240MHz according to the formula:

$$Fvco\_out = Fref \times (n+1)$$

The VCO's output frequency is routed through a postscaler so the final PLL output frequency is given by:

$$Fpll\_out = Fvco\_out / 2^{m}$$

where *m* is the value on the postscaler and can range from 0 to 7.

Example: Let Fref = 32 MHz, n = 4, and m = 3, using the formulas gives:

$Fpll\_out = (32\ MHz \times (4+1)) / 8$

Fpll_out = 20MHz.

For the 4MHz input crystal the valid range of *n* will be from 19 to 59, producing the same VCO output range, 80MHz to 240MHz.

6.3.6 PLL Lock Time User Notes

The PLL's Voltage Controlled Oscillator (VCO) has a characterized operating range extending from 80MHz to 240MHz. The PLL is programmable via a divide by *n+1* register, able to take on values varying between 1 and 128. For higher values of *n*, PLL lock time becomes an issue. It is recommended to avoid values of *n* resulting in the VCO frequency being greater than 240MHz. The graphic in **Figure 6-7** depicts the range of recommended output frequencies of VCO_OUT, plotting *n versus* the input frequency (Fref). The lower the value of *n*, the quicker the PLL will be able to lock.

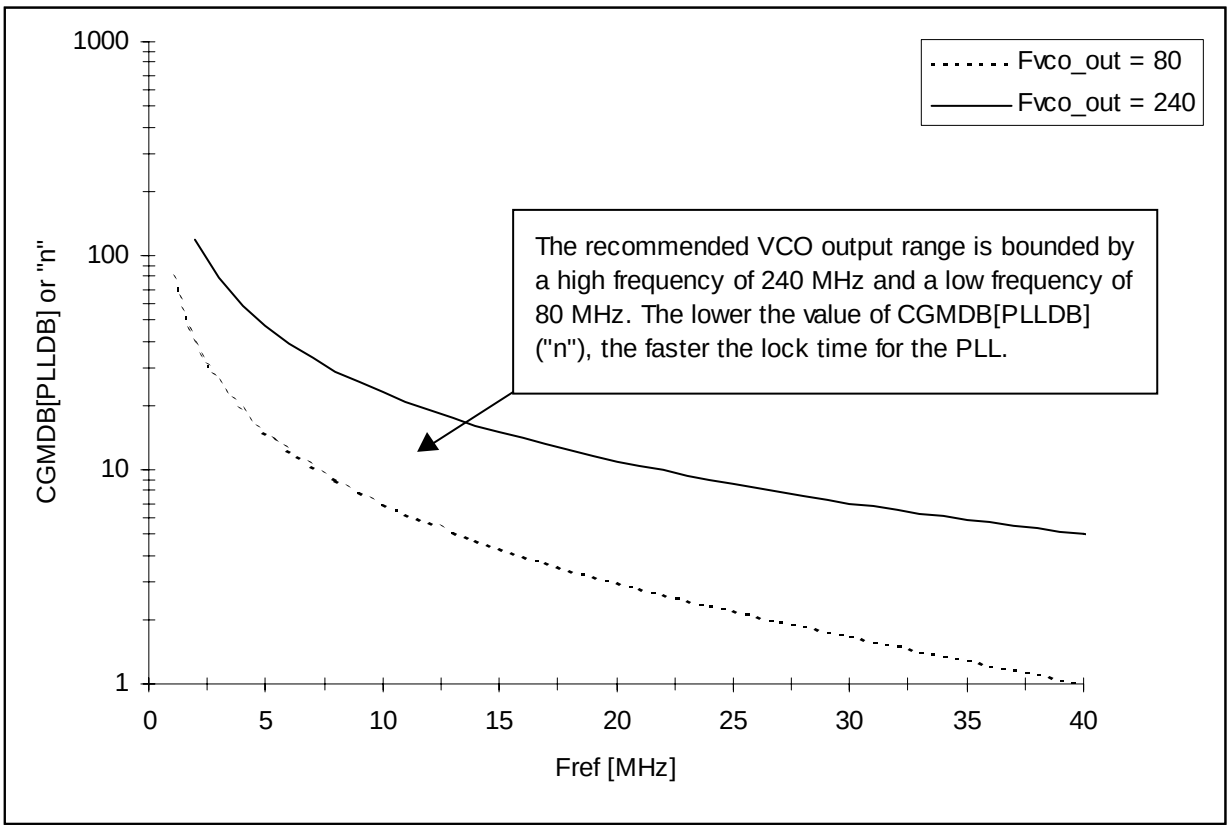


Figure 6-7. PLL Output Frequency vs. Input Frequency

The lock time of the PLL is, in many applications, the most critical PLL design parameter. Proper use of the PLL ensures the highest stability and lowest lock time.

6.3.6.1 PLL Lock Time Determination

Typical control systems refer to the lock time as the reaction time, within specified tolerances, of the system to a step input. In a PLL the step input occurs when the PLL is turned on or when it suffers a noise hit. The tolerance is usually specified as a percent of the step input or when the output settles to the desired value plus or minus a percent of the frequency change. Therefore, the reaction time is constant in this definition regardless of the size of the step input.

When the PLL is coming from a powered down state (PDN is high) to a powered up condition (PDN is low) the maximum lock time is 10msec.

Other systems refer to lock time as the time the system takes to reduce the error between the actual output and the desired output to within specified tolerances. Therefore, the lock time varies according to the original error in the output. Minor errors may be shorter or longer in many cases.

6.3.6.2 PLL Parametric Influences on Reaction Time

Lock time is designed to be as short as possible while still providing the highest possible stability. Many factors directly and indirectly affect the lock time.

The most critical parameter affecting the reaction time of the PLL, is the Reference Frequency (Fref). This frequency is the input to the phase detector and controls how often the PLL makes corrections. For stability, the corrections must be small compared to the desired frequency, so several corrections are required to reduce the frequency error. Therefore, the slower the Fref, the longer it takes to make these corrections.

Temperature and processing also can affect acquisition time because the electrical characteristics of the PLL change. The part operates as specified as long as these influences stay within the specified limits.

6.4 CGM Functional Detail

The CGM controls the PLL, detects PLL lock, and is used to generate the master clock to the SIM. The CPU clock is one half the frequency of the master clock and the IPBus clock is one fourth the frequency. The SIM handles these clock divisions. The master clock source can be either the oscillator output or the analog PLL output. The oscillator output (Fref) will typically be 4MHz, but a faster active clock can be driven into the XTAL pin at speeds of up to 240MHz. The PLL output can be up to 240MHz.

In order to use the PLL, the proper divide by factor and post scaler values should be programmed into the CGMDB register. Next, the PLL is turned on by setting the Power-Down (PDN) bit in the CGMCR to zero. The user should then wait for the PLL to achieve lock before changing the SEL bit to select the PLL output as the master clock.

6.4.1 PLL Frequency Lock Detector

This CGM function monitors the VCO output clock and sets the LCK1 and LCK0 bits in the CGM Control register based on the frequency accuracy. The lock detector is enabled with the LCKON bit of the CGMCR as well as the PDN bit. Once enabled, the detector starts two counters whose outputs are periodically compared. The input clocks to these counters are the VCO output clock divided by the divide-by factor, feedback, and the crystal reference clock, Fref. The period of the pulses being compared cover one whole period of each clock because the feedback clock doesn't guarantee a 50 percent duty cycle.

Counts are compared after 16, 32, and 64 cycles. If the counts match after 32 cycles, the LCK0 bit is set to 1. If the counts match after 64 cycles, the LCK1 bit is also set. The LCK bits stay set until the counts fail to match or if a new value is written to the PLLDB field or on reset caused by LCKON, PDN, or chip level reset. When the circuit sets LCK1, the two counters are reset and start the count again. The lock detector is designed so if LCK1 is reset to 0 because the counts did not match when checked after 64 cycles, the LCK0 bit can remain high if the counts matched after 32 cycles. This provides the processor the accuracy of the two clocks with respect to each other.

6.5 Module Memory Map

There are three registers on the CGM peripheral outlined in **Table 6-1.**

Table 6-1. CGM Memory Map (CGM_BASE = $1FFF10)

Address Offset	Register Acronym	Register Name	Access Type	Chapter Location
Base + $0	CGMCR	Control Register	Read/Write	Section 6.6.1
Base + $1	CGMDB	Divide-By Register	Read/Write	Section 6.6.2
Base + $2	CGMTOD	Time-of-Day Register	Read/Write	Section 6.6.3

Add. Offset	Register Name		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$0	CGMCR	R	0	0	LCK1	LCK0	SEL	0	0	0	0	LCK1_IE		LCK0_IE		LCK ON	TOD_ SEL	PDN
		W																
$1	CGMDB	R	POST			0	0	0	0	0	0	PLLDB						
		W																
$2	CGMTOD	R	0	0	0	0	TOD											
		W																

R 0 Read as 0
W Reserved

Figure 6-8. CGM Register Map Summary

6.6 Register Descriptions (CGM_BASE = $1FFF10)

6.6.1 Clock Generation Module (CGM) Control Register

Base + $0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	LCK1	LCK0	SEL	0	0	0	0	LCK1_IE		LCK0_IE		LCKON	TOD_SEL	PDN
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Figure 6-9. CGM Control Register (CGMCR)

See Programmer's Sheet on Appendix page B-13

6.6.1.1 Reserved—Bits 15–14

This bit field is reserved or not implemented. It is read as 0 and cannot be modified by writing.

6.6.1.2 Lock 1 Status (LCK1)—Bit 13

This bit shows the status of the lock detector state for the LCK1 circuit. Changes in the state of this bit can be used to cause interrupts in conjunction with the LCK1 Interrupt Enable bits. The LCK1 interrupt is cleared by writing 1 to this bit.

- 0 = PLL not locked
- 1 = PLL locked

6.6.1.3 Lock 0 Status (LCK0)—Bit 12

This bit shows the status of the lock detector state for the LCK0 circuit. Changes in the state of this bit can be used to cause interrupts in conjunction with the LCK0 Interrupt Enable bits. The LCK0 interrupt is cleared by writing 1 to this bit.

- 0 = PLL not locked
- 1 = PLL locked

6.6.1.4 Clock Source Select (SEL)—Bit 11

This bit is used to control the source of the master clock to the SIM.

- 0 = Oscillator output selected by default
- 1 = PLL output selected

6.6.1.5 Reserved—Bits 10–7

This bit field is reserved or not implemented. It is read as 0, and cannot be modified by writing.

6.6.1.6 Lock 1 Interrupt Enable (LCK1_IE)—Bits 6–5

An optional interrupt can be generated if the PLL lock status bit (LCK1) changes.

- 00 = Disable interrupt by default
- 01 = Enable interrupt on rising edge of LCK1
- 10 = Enable interrupt on falling edge of LCK1
- 11 = Enable interrupt on any edge of LCK1

6.6.1.7 Lock 0 Interrupt Enable (LCK0_IE)—Bits 4–3

An optional interrupt can be generated if the PLL Lock (LCK0) status bit changes.

- 00 = Disable interrupt by default
- 01 = Enable interrupt on rising edge of LCK0
- 10 = Enable interrupt on falling edge of LCK0
- 11 = Enable interrupt on any edge of LCK0

6.6.1.8 Lock Detector On (LCKON)—Bit 2

- 0 = Lock detector disabled by default
- 1= Lock detector enabled

6.6.1.9 Time-of-Day Clock Source Select (TOD_SEL)—Bit 1

This bit is used to select between two possible TIME_CLK sources. The oscillator can generate the TIME_CLK only when the input clock on either the EXTAL or XTAL pins in 4MHz or less. When driving high speed clocks into XTAL, the CGM must generate the TIME_CLK using the CGMTOD register. This bit is only reset by Power-On Reset (POR) conditions.

- 0 = TIME_CLK is generated by oscillator as default
- 1 = TIME_CLK is generated by CGM

6.6.1.10 PLL Power-Down (PDN)—Bit 0

The PLL can be turned off by setting the PDN bit to 1. There is a four IPBus clock delay from changing the bit to signaling the PLL. When the PLL is powered down, the clock select logic automatically switches to the oscillator output in order to prevent loss of clock to the core.

- 0 = PLL turned on
- 1 = PLL powered down by default

6.6.2 Clock Generation Module (CGM) Divide-By Register

Base + $1	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	POST			0	0	0	0	0	0	PLLDB						
Write																
Reset	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1

Figure 6-10. CGM Divide-By Register (CGMDB)

See Programmer's Sheet on Appendix page B-15

6.6.2.1 PLL Post Scaler (POST)—Bits 15–13

The output of the PLL is postscaler by one to 128 based on this field. When changing this field, it is recommended the SEL bit is set to choose the oscillator output, changing this field, then the SEL bit is returned to selecting the PLL's postscaler output.

- 000 = PLL output is divided by one by default
- 001 = PLL output is divided by two
- 010 = PLL output is divided by four
- 011 = PLL output is divided by eight
- 100 = PLL output is divided by 16
- 101 = PLL output is divided by 32
- 110 = PLL output is divided by 64
- 111 = PLL output is divided by 128

6.6.2.2 Reserved—Bits 12–7

This bit field is reserved or not implemented. It is read as 0 and cannot be modified by writing.

6.6.2.3 PLL Divide-By (PLLDB)—Bits 6–0

The VCO output frequency is controlled by the PLL divide-by value. Each time a new value is written into the PLLDB field, the Lock Detector circuit is reset. Before changing the divide-by value, it is recommended the SEL bit be set to choose the oscillator output. The VCO output frequency is determined by using the following formula:

$Fvco\_out = Fref \times (PLLDB + 1)$

6.6.3 Clock Generation Module (CGM) Time-of-Day Register

Base + $2	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	TOD											
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 6-11. CGM Time-of-Day Register (CGMTOD)

See Programmer's Sheet on Appendix page B-16

6.6.3.1 Reserved—Bits 15–12

This bit field is reserved or not implemented. It is read as 0 and cannot be modified by writing.

6.6.3.2 TOD Scale Factor (TOD)—Bits 11–0

The output of the oscillator is divided by (TOD + 1) and then divided by 2, generating the TIME_CLK used by the COP module when TOD_SEL is high. The value of TOD should be chosen to result in a TOD clock frequency in the range of 15.12KHz to 31.25KHz. This register is only reset during Power-On Reset (POR).

6.7 OCCS Resets

The CGM registers are reset by a chip level reset. This forces all registers to their reset state and selects the oscillator output as the master clock source for the SIM.

6.8 OCCS Interrupts

The CGM generates a single interrupt request to the INTC. This interrupt is generated by the lock detector circuitry LCK0 and LCK1 outputs and is enabled by the LCK0 Interrupt Enable and LCK1 Interrupt Enable bits in the CGMCR. This interrupt can be used to detect when the PLL goes into lock or when it falls out of lock. The interrupt is cleared by writing 1 to the LCK0 and/or LCK1 bits of the CGMCR.

Chapter 7
Power-On Reset (POR) and Computer Operating Properly (COP)

7.1 Introduction

The Power-on Reset (POR) function monitors the core power supply, the I/O, and analog power supply. If either of those power supplies are below their thresholds, the POR output for each respective supply is held high. Once the power supply goes above the thresholds, the POR outputs are held low.

Computer Operating Properly (COP) is also discussed in this chapter as it relates to resets.

7.2 Features

- The circuit monitors both the core power supply and peripheral power supply
- Holds a wide chip reset once either of these supply voltages are below the thresholds
- Generates the address of the reset vector provided to the core after exit Reset
- The address of reset vector (same as the COP Reset) is located at $1F0000

The COP module design features include:

- Programmable time-out period = (COP_PRESCALER × (CT + 1)) oscillator clock cycles, where CT can be from $0000 to $FFFF
- Programmable Wait and Stop mode operations
- COP timer is disabled while host CPU is in Debug mode

7.3 Block Diagram

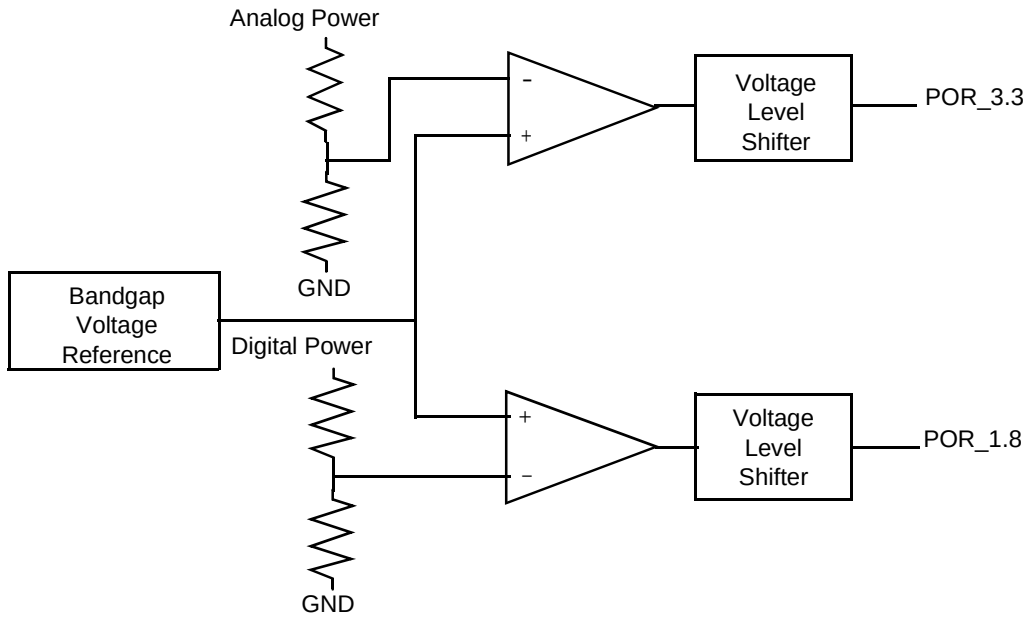


Figure 7-1. POR Module Block Diagram

7.4 Method of Operation

Starting with the chip unpowered, the analog and digital power supplies turned on, the bandgap voltage reference and the comparators will begin to function. The bandgap voltage reference will apply a temperature and supply stable voltage reference to the positive inputs of the comparators. Negative inputs of the comparators are connected to voltage points that move proportionately with respect to the analog and digital power supplies.

Initially, the bandgap voltage reference point is greater than the power supply reference signals and the output of the comparators is high. As each power supply goes above it's trip point, the voltage on the respective comparators negative input will become higher in value than the bandgap voltage reference voltage on the positive input to the comparator and the output of the comparator will go low. If either power supply drops below the trip point the respective POR output will again go high.

For the analog power supply, the POR trip point is:

Absolute Minimum	Nominal	Absolute Maximum
2.8V	2.85V	2.9V

For the digital power supply the POR trip point is:

Absolute Minimum	Nominal	Absolute Maximum
1.62V	1.66V	1.7V

This means, as long as the analog power supply is below 2.8V, the POR_3p3 will be high. When the analog power supply exceeds 2.9V the POR_3p3 output will be low. Respectively, for the digital power supply, when the digital power supply is below 1.62V the POR_1p8 output will be high. When the digital power supply is above 1.7V the POR_1p8 output will be low.

7.5 Computer Operating Properly (COP) Module

The Computer Operating Properly (COP) module is used to help software recover from runaway code. The COP is a free-running down counter, once enabled is designed to generate a Reset upon reaching zero. Software must periodically service the COP in order to clear the counter and prevent a reset.

7.5.1 COP Functional Description

When the COP is enabled, each positive edge of OSCCLK will cause the counter to decrement by one. If the count reaches a value of $0000, then the COP_$\overline{\text{RST}}$ signal is asserted and the chip is reset. In order for the CPU to show it is operating properly, it must perform a service routine prior to the count reaching $0000. The service routine consists of writing $5555 followed by $AAAA to COPCTR.

7.5.2 Time-Out Specifications

The COP uses a 16-bit counter, being clocked by the crystal oscillator clock prescaled by 128. **Table 7-1** presents the range of time-out values supported as a function of oscillator frequency.

Table 7-1. COP Time-Out Ranges as a Function of Oscillator Frequency

CT	2 MHz	4MHz
$0000	64 µsec	32 µsec
$FFFF	4.2 sec	2.1 sec

For a crystal operating at 4MHz the clock to the COP counter will be 31.25KHz. The value of the COPTO register can be programmed from 1 to 65535 giving a time-out period range from 32µsec minimum to 2.1sec maximum.

7.5.3 COP After Reset

COPCTL is cleared out of reset. Thus the counter is disabled by default. In addition, COPTO is set to it's maximum value of $FFFF during reset so the counter is loaded with a maximum time-out period when reset is released.

7.5.4 Wait Mode Operation

If both CEN and CWEN are set to one and the Wait mode is entered, the COP counter will continue to count down. If either CEN or CWEN is set to 0 when Wait mode is entered, the counter will be disabled and will reload using the value in the COPTO register.

7.5.5 Stop Mode Operation

If both CEN and CSEN set to one and the Stop mode is entered, the COP counter will continue to count down. If either CEN or CSEN is set to 0 when Stop mode is entered, the counter will be disabled and will reload using the value in the COPTO register.

7.5.6 Debug Mode Operation

The COP counter does not count when the chip is in the Debug mode. Additionally, the CEN bit in the COPCTL always reads as 0 when the chip is in the Debug mode. The actual value of CEN is unaffected by debug however, and it resumes it's previously set value upon exiting Debug.

7.6 Operating Modes

The COP module design contains two major modes of operation:

- Functional mode

  The COP by default is in this mode and will remain in this mode for as long as the SCANTESTMODE input remains low.

- Debug mode

  The COP timer is stopped while the processor is in the Debug mode. If the COP is enabled, the timer will resume, counting upon exiting Debug mode. The CEN bit in COPCTL register always reads as 0 when in the Debug mode, even when it has a value of one.

7.7 Block Diagram

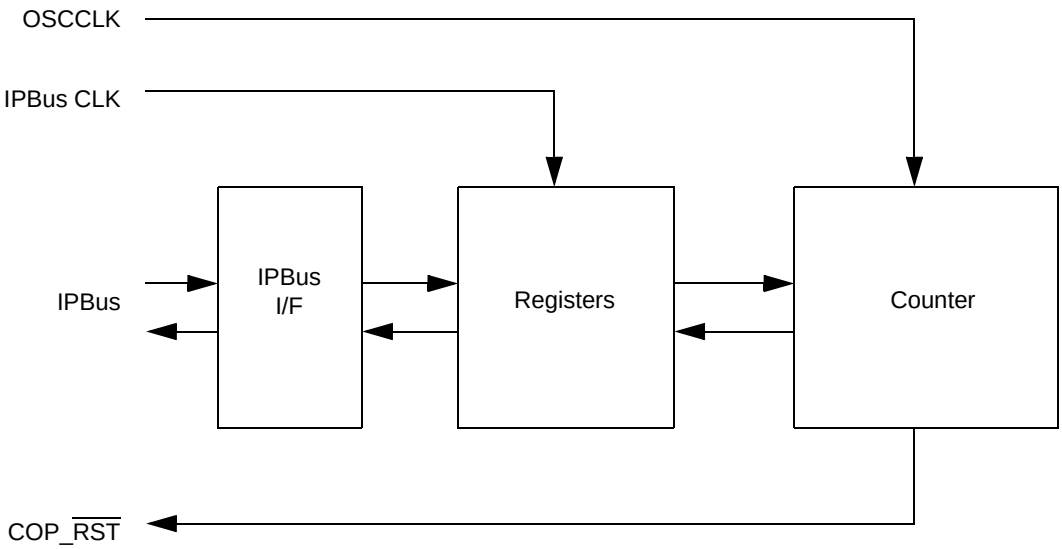


Figure 7-2. COP Module Block Diagram and Interface Signals

7.8 Module Memory Map

There are three registers on the COP peripheral described in **Table 7-2.** The registers are summarized in **Figure 7-2.**

Table 7-2. COP Module Memory Map (COP_BASE = $1FFFD0)

Address Offset	Register Acronym	Register Name	Access Type	Chapter Location
Base + $0	COPCTL	Control Register	Read/Write	Section 7.9.1
Base + $1	COPTO	Time-Out Register	Read/Write	Section 7.9.2
Base + $2	COPCTR	Counter Register	Read/Write	Section 7.9.3

Add. Offset	Register Name		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$0	COPCTL	R	0	0	0	0	0	0	0	0	0	0	0	BYPS	CSEN	CWEN	CEN	CWP
		W																
$1	COPTO	R	TIMEOUT															
		W																
$2	COPCTR	R	COUNT															
		W	SERVICE															

R 0 Read as 0
W Reserved

Figure 7-2. COP Register Map Summary

7.9 Register Descriptions (COP_BASE = $1FFFD0)

7.9.1 COP Control Register (COPCTL)

Base + $0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	0	0	0	BYPS	CSEN	CWEN	CEN	CWP
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 7-3. COP Control Register (COPCTL)

See Programmer's Sheet on Appendix page B-18

7.9.1.1 Reserved—Bits 15–5

This bit field is reserved or not implemented. Each bit in the field is read as 0 and cannot be modified by writing.

7.9.1.2 Bypass (BYPS)—Bit 4

This bit is intended for factory use only. Setting this bit allows testing time of the COP to be accelerated by routing the IPBus clock to the counter instead of the OSCCLK. This bit should not be set during normal operation of the chip. If this bit is used, however, it should only be changed while the CEN bit is set to 0.

- 0 = Counter uses OSCCLK (default)
- 1 = Counter uses IPBus clock

7.9.1.3 COP Stop Mode Enable (CSEN)—Bit 3

This bit controls the operation of the COP counter in the Stop mode. This bit can only be changed when the CWP bit is set to 0.

- 0 = COP counter will stop in the Stop mode (default)
- 1 = COP counter will run in the Stop mode if CEN is set to 1

7.9.1.4 COP Wait Mode Enable (CWEN)—Bit 2

This bit controls the operation of the COP counter in the Wait mode. This bit can only be changed when the CWP bit is set to 0.

- 0 = COP counter will stop in the Wait mode (default)
- 1 = COP counter will run in the Wait mode if CEN is set to 1

7.9.1.5 COP Enable (CEN)—Bit 1

This bit controls the operation of the COP counter. This bit can only be changed when the CWP bit is set to 0. This bit always reads as 0 when the chip is in the Debug mode.

- 0 = COP counter is disabled (default)
- 1 = COP counter is enabled

7.9.1.6 COP Write Protect (CWP)—Bit 0

This bit controls the write protection feature of the COP Control (COPCTL) register and the COP Time-Out (COPTO) register. Once set, this bit can only be cleared by resetting the module.

- 0 = COPCTL and COPTO are readable and writable (default)
- 1 = COPCTL and COPTO are read only

7.9.2 COP Time-Out Register (COPTO)

Base + $1	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read Write	TIMEOUT															
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 7-4. COP Time-Out Register (COPTO)

See Programmer's Sheet on Appendix page B-19

7.9.2.1 COP Time-Out Period (TIMEOUT)—Bits 15–0

The value in this register determines the time-out period of the COP counter. TIMEOUT should be written before the COP is enabled. Once the COP is enabled, the recommended procedure for changing TIMEOUT is to disable the COP, write to COPTO, then re-enable the COP, ensuring the new TIMEOUT is loaded into the counter. Alternatively, the CPU can write to COPTO, then write the proper patterns to COPCTR, causing the counter to reload with the new TIMEOUT value. The COP counter is not reset by a write to COPTO. Changing TIMEOUT while the COP is enabled will result in a time-out period differing from the expected value. These bits can only be changed when the CWP bit is set to 0.

7.9.3 COP Counter Register (COPCTR)

Base + $2	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	COUNT															
Write	SERVICE															
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 7-5. COP Counter Register (COPCTR)

See Programmer's Sheet on Appendix page B-20

7.9.3.1 COP Count (COUNT)—Bits 15–0

This is the current value of the COP counter as it counts down from the time-out value to zero. A reset is issued when this count reaches zero.

7.9.3.2 COP Service (SERVICE)—Bits 15–0

When enabled, the COP requires a service sequence be performed periodically in order to clear the COP counter and prevent a reset from being issued. This routine consists of writing $5555 to the COPCTR followed by writing $AAAA before the time-out period expires. The writes to COPCTR must be performed in the correct order, but any number of other instructions, and writes to other registers, may be executed between the two writes.

7.10 Clocks

The COP timer base is the oscillator clock divided by a fixed prescalar value. The prescalar divisor for this chip is 128.

7.11 Resets

Any system reset forces all registers to their reset state, clearing the $\overline{\text{COP\_RST}}$ signal when it is asserted. The counter will be loaded with its maximum value of $FFFF, but it will not start when Reset is released because the CEN bit is disabled by default.

7.12 Interrupts

The COP module does not generate any interrupts. It does generate the $\overline{\text{COP\_RST}}$ signal when the counter reaches a value of $0000, causing a chip wide reset.

Chapter 8
Interrupt Controller (ITCN)

8.1 Introduction

The Interrupt Controller (ITCN) is responsible for arbitrating all interrupt requests according to the priority level of the each request. This includes all external interrupt sources, such as $\overline{\text{IRQA}}$, $\overline{\text{IRQB}}$, and so on, peripheral generated interrupt requests and core generated interrupt requests. After arbitration, the interrupt controller will compare the priority of the current interrupt request with the current priority level of the core and if the request has higher priority to generate a single enabled interrupt request signal to the core.

There are five levels of interrupt priority provided by the56800E core, illustrated in **Table 8-1.**

1. LP = the lowest level is generated by the SWILP instruction
2. Level 0 = maskable with the lowest priority of the three maskable interrupts
3. Level 1 = maskable
4. Level 2 = maskable
5. Level 3 = the highest priority is a non-maskable interrupt

Device interrupt priority levels are programmable via the Interrupt Priority Register (IPR).

The interrupt controller is also responsible for generating the vector address of the current interrupt request. This is based on the Vector Address Base (VAB) register and the event initiating the request. The interrupt controller predefines the Vector Table offsets for all possible interrupt sources and will generate the Vector Address of the request by adding the programmable VAB register to the Vector Table offset.

Table 8-1. Interrupt Priority Level

IPL	Description	Priority	Interrupt Sources
LP	Maskable	Lowest	SWILP instruction
0	Maskable	—	On-chip peripherals, IRQA and IRQB, SWI #0 instruction
1	Maskable	—	On-chip peripherals, IRQA and IRQB, SWI #1 instruction, EOnCE interrupts
2	Maskable	—	On-chip peripherals, IRQA and IRQB, SWI #2 instruction, EOnCE interrupts
3	Non-Maskable	Highest	Illegal instruction, HWS overflow, SWI #3 instruction, EOnCE interrupts, Misaligned data access

External interrupt sources such as $\overline{\text{IRQA}}$ and $\overline{\text{IRQB}}$ are programmable to either level sensitive or edge triggered. Level sensitive interrupts remain active as long as the input remains low and are cleared when the input level goes high. The edge sensitive interrupts are latched as pending on the high-to-low transition of the interrupt input and are cleared when the interrupt is serviced.

The Vector Table is structured as two words per vector. This implies the interrupt vector offset, added to the vector base address, will be the vector number multiplied by two. If the first instruction of an interrupt vector is a JSR or BSR, the core assumes a standard long interrupt. This is the normal case.

The core then saves the status register and program counter and vectors to the address pointed to by the JSR. The interrupt is cleared by executing the Return from Interrupt Instruction (RTI or RTID) at the end of the interrupt service routine.

The interrupt controller can support up to two fast interrupts. There are four programmable registers in the controller, two for each fast interrupt, allowing set-up of a vector number to be configured as a fast interrupt, and a 21-bit absolute vector address pointing to the interrupt service routine.

When the Fast Interrupt Vector Number register is programmed, the Interrupt Controller will intercept the normal vector table, processing and insert the absolute address into the core via the VAB bus. As long as the first instruction of the interrupt service routine is not a JSR or a BSR, the core will interpret the interrupt as a fast interrupt and begin inserting the code into the pipeline until a Fast Return from Interrupt (FRTID) is executed. The interrupt priority *must be set to level two for the fast interrupt to operate properly*. Further, there can not be a JSR or BSR as the first instruction of the fast interrupt service routine. The return from interrupt must use the fast return from interrupt instruction (FRTID) to clear the interrupt.

Reset is considered to be the highest priority interrupt and will take precedence over all other interrupts. If the reset pin is pulled low the interrupt controller will generate a reset vector address for the core and assert the re-signal in the core.

8.2 Features

The ITCN module design includes these distinctive features:

- Programmable priority levels for each IRQ
- Two programmable Fast Interrupts
- Notification to SIM module to restart clocks out of Wait and Stop modes

8.3 ITCN Module Signal Description

The ITCN module interfaces with the IPBus, the 56800E core, and the IRQ sources. There are no chip outputs driven directly by this module, but the $\overline{\text{IRQA}}$ and $\overline{\text{IRQB}}$ chip inputs do come to the ITCN where they are re-synchronized to the system clock before use.

8.4 Block Diagram

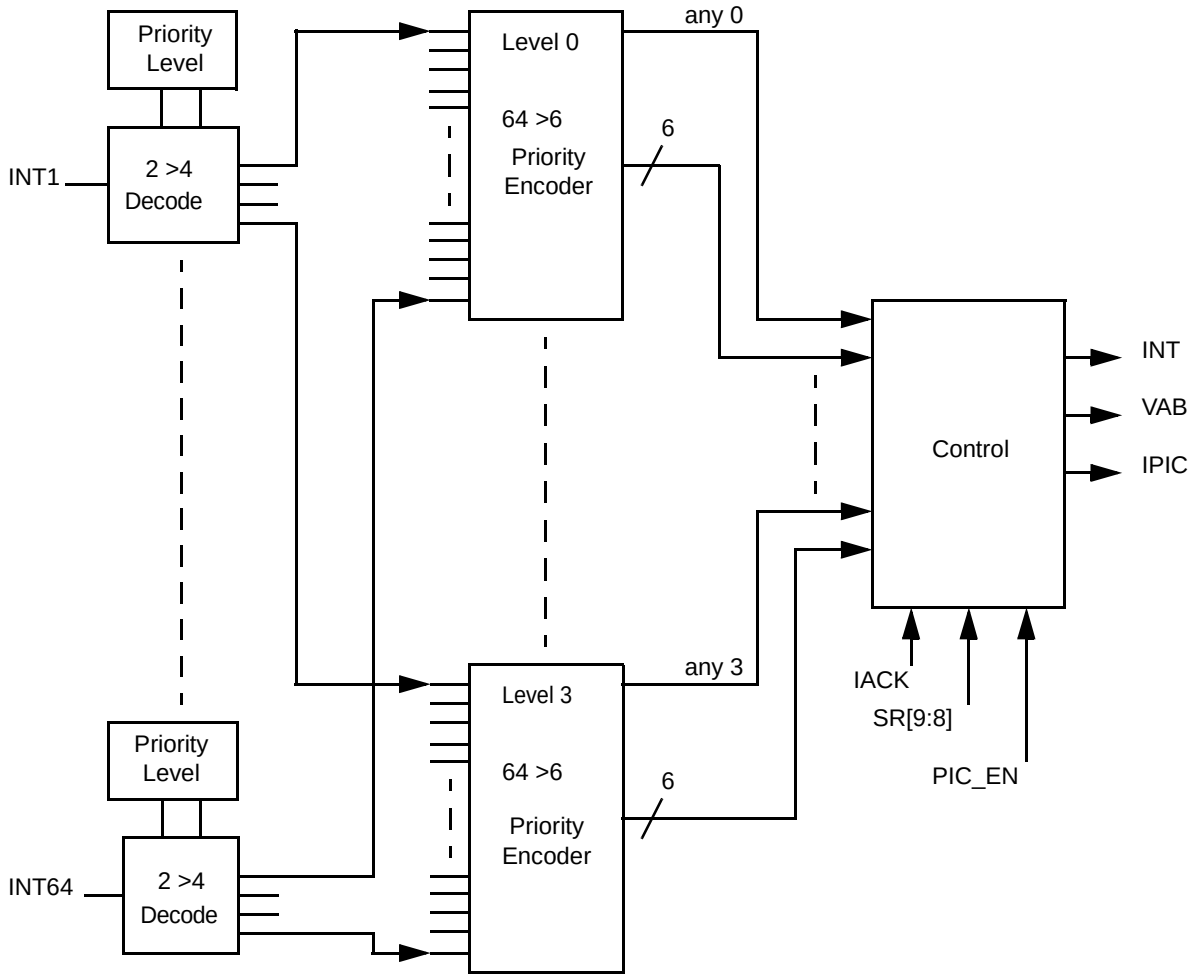


Figure 8-1. Interrupt Controller Block Diagram

8.5 Functional Description

The Interrupt Controller is a slave on the IPBus. Its registers allow each of the interrupt sources to be set to one of four priority levels, excluding certain interrupts of fixed priority. Next, all of the interrupt requests of a given level are priority encoded to determine the lowest numerical value of the active interrupt requests for that level. Within a given priority level, number zero is the highest priority and number 64 is the lowest.

8.5.1 Interrupt Vector Map

Table 8-2 shows the list of interrupt vectors on the 56852 device. As can be seen from the table, the total vector table size is 64 vectors or 128 words of memory. This table also shows the allowable priority range or fixed priority for each IRQ.

Table 8-2. Interrupt Vector Table Contents

Peripheral	Vector Number	Priority Level	Vector Base Address +	Interrupt Function
core	0	3	P:$00	Reserved
core	1	3	P:$02	Reserved
core	2	3	P:$04	Illegal Instruction
core	3	3	P:$06	SW Interrupt 3
core	4	3	P:$08	HW Stack Overflow
core	5	3	P:$0A	Misaligned Long Word Access
core	6	1-3	P:$0C	EOnCE Step Counter
core	7	1-3	P:$0E	EOnCE Breakpoint Unit 0
core	8	1-3	P:$10	Reserved
core	9	1-3	P:$12	EOnCE Trace Buffer
core	10	1-3	P:$14	EOnCE Transmit Register Empty
core	11	1-3	P:$16	EOnCE Receive Register Full
core	12	0-3	P:$18	Reserved
core	13	0-3	P:$1A	Reserved
core	14	2	P:$1C	SW Interrupt 2
core	15	1	P:$1E	SW Interrupt 1
core	16	0	P:$20	SW Interrupt 0
core	17	0-2	P:$22	IRQA
core	18	0-2	P:$24	IRQB
core	19	0-2	P:$26	Reserved
PLL	20	0-2	P:$28	PLL Loss Of Lock
—	21	0-2	P:$2A	Reserved
—	22	0-2	P:$2C	Reserved
—	23	0-2	P:$2E	Reserved
—	24	0-2	P:$30	Reserved
—	25	0-2	P:$32	Reserved
—	26	0-2	P:$34	Reserved
—	27	0-2	P:$36	Reserved
ISSI	28	0-2	P:$38	SSI Receive Data with Exception Status
ISSI	29	0-2	P:$3A	SSI Receive Data
—	30	0-2	P:$3C	Reserved
ISSI	31	0-2	P:$3E	SSI Transmit Data with Exception Status
ISSI	32	0-2	P:$40	SSI Transmit Data
—	33	0-2	P:$42	Reserved

Table 8-2. Interrupt Vector Table Contents (Continued)

Peripheral	Vector Number	Priority Level	Vector Base Address +	Interrupt Function
—	34	0-2	P:$44	Reserved
—	35	0-2	P:$46	Reserved
—	36	0-2	P:$48	Reserved
—	37	0-2	P:$4A	Reserved
—	38	0-2	P:$4C	Reserved
—	39	0-2	P:$4E	Reserved
SPI	40	0-2	P:$50	SPI Receiver Full
SPI	41	0-2	P:$52	SPI Transmitter Empty
SCI	42	0-2	P:$54	SCI Transmitter Empty
SCI	43	0-2	P:$56	SCI Transmitter Idle
SCI	44	0-2	P:$58	SCI Receiver Idle
SCI	45	0-2	P:$5A	SCI Receiver Error
SCI	46	0-2	P:$5C	SCI Receiver Full
—	47	0-2	P:$5E	Reserved
—	48	0-2	P:$60	Reserved
—	49	0-2	P:$62	Reserved
—	50	0-2	P:$64	Reserved
—	51	0-2	P:$66	Reserved
Timer	52	0-2	P:$68	Timer Compare 0
Timer	53	0-2	P:$6A	Timer Overflow 0
Timer	54	0-2	P:$6C	Timer Input Edge Flag 0
Timer	55	0-2	P:$6E	Timer Compare 1
Timer	56	0-2	P:$70	Timer Overflow 1
Timer	57	0-2	P:$72	Timer Input Edge Flag 1
Timer	58	0-2	P:$74	Timer Compare 2
Timer	59	0-2	P:$76	Timer Overflow 2
Timer	60	0-2	P:$78	Timer Input Edge Flag 2
Timer	61	0-2	P:$7A	Timer Compare 3
Timer	62	0-2	P:$7C	Timer Overflow 3
Timer	63	0-2	P:$7E	Timer Input Edge Flag 3
core	64	-1	P:$80	SW Interrupt LP

8.6 Operating Modes

The ITCN module design contains two major modes of operation:

1. Functional Mode
   The ITCN is in this mode by default.
2. Test Mode

This mode is entered by setting the proper bits within the Control register. This mode allows the IRQ sources to be overridden by values in the test registers and also to override the values of the current interrupt priority level, PIC_EN, and IACK from the 56800E core.

8.7 Wait and Stop Modes Operations

During Wait and Stop modes the system clocks and the 56800E core are turned off. ITCN will signal a pending IRQ to the System Integration Module (SIM) to restart the clocks and service the IRQ. An IRQ can only wake up the core if the IRQ is enabled prior to entering the Wait or Stop mode. Also, the $\overline{\text{IRQA}}$ and $\overline{\text{IRQB}}$ signals automatically become low level sensitive in these modes even if the Control register bits are set to make them falling edge sensitive. This is because there is no clock available to detect the falling edge.

8.8 Module Memory Map

There are 18 registers on the ITCN peripheraldescribed in **Table 8-3.**

Table 8-3. Module Memory Map (ITCN_BASE = $FFF20)

Address Offset	Register Acronym	Register Name	Access Type	Chapter Location
Base + $0	IPR0	Interrupt Priority Register 0	Read/Write	Section 8.9.1
Base + $1	IPR1	Interrupt Priority Register 1	Read/Write	Section 8.9.2
Base + $2	IPR2	Interrupt Priority Register 2	Read/Write	Section 8.9.3
Base + $3	IPR3	Interrupt Priority Register 3	Read/Write	Section 8.9.4
Base + $4	IPR4	Interrupt Priority Register 4	Read/Write	Section 8.9.5
Base + $5	IPR5	Interrupt Priority Register 5	Read/Write	Section 8.9.6
Base + $6	IPR6	Interrupt Priority Register 6	Read/Write	Section 8.9.7
Base + $7	IPR7	Interrupt Priority Register 7	Read/Write	Section 8.9.8
Base + $8	VBA	Vector Base Address Register	Read/Write	Section 8.9.9
Base + $9	FIM0	Fast Interrupt Match Register 0	Read/Write	Section 8.9.10
Base + $A	FIVAL0	Fast Interrupt Vector Address Low 0	Read/Write	Section 8.9.11
Base + $B	FIVAH0	Fast Interrupt Vector Address High 0	Read/Write	
Base + $C	FIM1	Fast Interrupt Match Register 1	Read/Write	Section 8.9.10
Base + $D	FIVAL1	Fast Interrupt Vector Address Low 1	Read/Write	Section 8.9.12
Base + $E	FIVAH1	Fast Interrupt Vector Address High 1	Read/Write	
Base + $F	IRQP0	IRQ Pending Register 0	*Read-Only*	Section 8.9.13
Base + $30	IRQP1	IRQ Pending Register 1	*Read-Only*	
Base + $31	IRQP2	IRQ Pending Register 2	*Read-Only*	
Base + $32	IRPQ3	IRQ Pending Register 3	*Read-Only*	
Base + $37	ICTL	Interrupt Control Register	Read/Write	Section 8.9.14

Add. Offset	Register Name		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$0	IPR0	R	0	0	BKPT_U0 IPL		STPCNT IPL		0	0	0	0	0	0	0	0	0	0
		W																
$1	IPR1	R	0	0	0	0	0	0	0	0	0	0	RX_REG IPL		TX_REG IPL		TRBUF IPL	
		W																
$2	IPR2	R	0	0	0	0	0	0	0	0	LOCK IPL		0	0	IRQB IPL		IRQA IPL	
		W																
$3	IPR3	R	SSI_TD IPL		SSI_TDES IPL		0	0	SSI_RD IPL		SSI_RDES IPL		0	0	0	0	0	0
		W																
$4	IPR4	R	SPI_RCV IPL		0	0	0	0	0	0	0	0	0	0	0	0	0	0
		W																
$5	IPR5	R	0	0	0	0	SCI_RCV IPL		SCI_RERR IPL		SCI_RIDL IPL		SCI_TIDL IPL		SCI_XMIT IPL		SPI_XMIT IPL	
		W																
$6	IPR6	R	TOVF1 IPL		TCMP1 IPL		TINP0 IPL		TOVFO IPL		TCMP0 IPL		0	0	0	0	0	0
		W																
$7	IPR7	R	0	0	TINP3 IPL		TOVF3 IPL		TCMP3 IPL		TINP2 IPL		TOVF2 IPL		TCMP2 IPL		TINP1 IPL	
		W																
$8	VBA	R	0	0	0	VECTOR BASE ADDRESS												
		W																
$9	FIM0	R	0	0	0	0	0	0	0	0	0	0	FAST INTERRUPT 0					
		W	0	0	0	0	0	0	0	0	0	0						
$A	FIVAL0	R	FAST INTERRUPT 0 VECTOR ADDRESS LOW															
		W																
$B	FIVAH0	R	0	0	0	0	0	0	0	0	0	0	0	FAST INTERRUPT 0 VECTOR ADDRESS HIGH				
		W	0	0	0	0	0	0	0	0	0	0	0					
$C	FIM1	R	0	0	0	0	0	0	0	0	0	0	FAST INTERRUPT 1					
		W	0	0	0	0	0	0	0	0	0	0						
$D	FIVAL1	R	FAST INTERRUPT 1 VECTOR ADDRESS LOW															
		W																
$E	FIVAH1	R	0	0	0	0	0	0	0	0	0	0	0	FAST INTERRUPT 1 VECTOR ADDRESS HIGH				
		W	0	0	0	0	0	0	0	0	0	0	0					
$F	IRQP0	R	PENDING [16:1]															
		W																
$30	IRQP1	R	PENDING [32:17]															
		W																
$31	IRQP2	R	PENDING [48:33]															
		W																
$32	IRQP3	R	PENDING [64:49]															
		W																
$37	ICTL	R	INT	IPIC		VN							INT_ DIS		IRQB STATE	IRQA STATE	IRQB EDG	IRQA EDG
		W																

R	0	Read as 0
W		Reserved

Figure 8-2. ITCN Register Map Summary

8.9 Register Descriptions (ITCN_BASE = $1FFF20)

8.9.1 Interrupt Priority Register 0 (IPR0)

Base + $0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	BKPT_U0 IPL		STPCNT IPL		0	0	0	0	0	0	0	0	0	0
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-3. Interrupt Priority Register 0 (IPR0)

See Programmer's Sheet on Appendix page B-20

8.9.1.1 Reserved—Bit 15–14

This bit field is reserved or not implemented. It is read as 0 and cannot be modified by writing.

8.9.1.2 Breakpoint Unit 0 EOnCE Interrupt Priority Level (BKPT_U0 IPL)—Bits 13–12

This bit field is used to set the interrupt priority levels for this EOnCE IRQ. This IRQ is limited to priorities 1-3. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 1
- 10 = IRQ is priority level 2
- 11 = IRQ is priority level 3

8.9.1.3 EOnCE Step Counter Interrupt Priority Level (STPCNT IPL)—Bits 11–10

This bit field is used to set the interrupt priority levels for this EOnCE IRQ. This IRQ is limited to priorities 1-3. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 1
- 10 = IRQ is priority level 2
- 11 = IRQ is priority level 3

8.9.1.4 Reserved—Bits 9–0

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.2 Interrupt Priority Register 1 (IPR1)

Base + $1	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	0	0	RX_REG IPL		TX_REG IPL		TRBUF IPL	
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-4. Interrupt Priority Register 1 (IPR1)

See Programmer's Sheet on Appendix page B-21

8.9.2.1 Reserved—Bits 15–6

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.2.2 Receive Empty Interrupt Priority Level (RX_REG IPL)—Bits 5–4

These bits are used to set the interrupt priority levels for this EOnCE IRQ. This IRQ is limited to priorities 1-3. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 1
- 10 = IRQ is priority level 2
- 11 = IRQ is priority level 3

8.9.2.3 Transmit Full Interrupt Priority Level (TX_REG IPL)—Bits 3–2

These bits are used to set the interrupt priority levels for this EOnCE IRQ. This IRQ is limited to priorities 1-3. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 1
- 10 = IRQ is priority level 2
- 11 = IRQ is priority level 3

8.9.2.4 Trace Buffer Interrupt Priority Level (TRBUF IPL)—Bits 1–0

These bits are used to set the interrupt priority levels for this EOnCE IRQ. This IRQ is limited to priorities 1-3. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 1
- 10 = IRQ is priority level 2

- 11 = IRQ is priority level 3

8.9.3 Interrupt Priority Register 2 (IPR2)

Base + $2	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	LOCK IPL		0	0	IRQB IPL		IRQA IPL	
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-5. Interrupt Priority Register 2 (IPR2)

See Programmer's Sheet on Appendix page B-22

8.9.3.1 Reserved—Bits 15–8

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.3.2 Loss of Lock Interrupt Priority Level (LOCK IPL)—Bits 7–6

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.3.3 Reserved—Bits 5–4

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.3.4 External IRQ B Interrupt Priority Level (IRQB IPL)—Bits 3–2

These two bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.3.5 External IRQ A Interrupt Priority Level (IRQA IPL)—Bits 1–0

These two bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.4 Interrupt Priority Register 3 (IPR3)

Base + $3	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	ISSI_TD IPL		ISSI_TDES IPL		0	0	ISSI_RD IPL		ISSI_RDES IPL		0	0	0	0	0	0
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-6. Interrupt Priority Register 3 (IPR3)

See Programmer's Sheet on Appendix page B-23

8.9.4.1 Transmit Data Interrupt Priority Level (SSI_TD IPL)—Bits 15–14

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.4.2 Transmit Data with Exception Status Interrupt Priority Level (SSI_TDES IPL)—Bits 13–12

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.4.3 Reserved—Bits 11–10

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.4.4 Receive Data Interrupt Priority Level (SSI_RD IPL)—Bits 9–8

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.4.5 Receive Data with Exception Status Interrupt Priority Level (SSI_RDES IPL)—Bits 7–6

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.4.6 Reserved—Bits 5–0

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.5 Interrupt Priority Register 4 (IPR4)

Base + $4	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	SPI_RCV IPL		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-7. Interrupt Priority Register 4 (IPR4)

See Programmer's Sheet on Appendix page B-24

8.9.5.1 Receiver Full Interrupt Priority Level (SPI_RCV IPL)—Bits 15–14

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.5.2 Reserved—Bits 13–0

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.6 Interrupt Priority Register 5 (IPR5)

Base + $5	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	SCI_RCV IPL		SCI_RERR IPL		SCI_RIDL IPL		SCI_TIDL IPL		SCI_XMIT IPL		SPI_XMIT IPL	
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-8. Interrupt Priority Register 5 (IPR5)

See Programmer's Sheet on Appendix page B-25

8.9.6.1 Reserved—Bits 15–12

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.6.2 Receiver Full Interrupt Priority Level (SCI_RCV IPL)—Bits 11–10

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.6.3 Receiver Error Interrupt Priority Level (SCI_RERR IPL)—Bits 9–8

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.6.4 Receiver Idle Interrupt Priority Level (SCI_RIDL IPL)–Bits 7–6

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.6.5 Transmitter Idle Interrupt Priority Level (SCI_TIDL IPL)—Bits 5–4

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.6.6 Transmitter Empty Interrupt Priority Level (SCI_XMIT IPL)—Bits 3–2

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.6.7 Transmitter Empty Interrupt Priority Level (SPI_XMIT IPL)—Bits 1–0

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.7 Interrupt Priority Register 6 (IPR6)

Base + $6	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	TOVF1 IPL		TCMP1 IPL		TINP0 IPL		TOVF0 IPL		TCMP0 IPL		0	0	0	0	0	0
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-9. Interrupt Priority Register 6 (IPR6)

See Programmer's Sheet on Appendix page B-27

8.9.7.1 Timer Overflow Interrupt Priority Level (TOVF1 IPL)—Bits 15–14

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.7.2 Timer Compare Interrupt Priority Level (TCMP1 IPL)—Bits 13–12

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.7.3 Timer Input Edge Interrupt Priority Level (TINP0 IPL)—Bits 11–10

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.7.4 Timer Overflow Interrupt Priority Level (TOVF0 IPL)—Bits 9–8

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.7.5 Timer Compare Interrupt Priority Level (TCMP0 IPL)—Bits 7–6

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.7.6 Reserved—Bits 5–0

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.8 Interrupt Priority Register 7 (IPR7)

Base + $7	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	TINP3 IPL		TOVF3 IPL		TCMP3 IPL		TINP2 IPL		TOVF2 IPL		TCMP2 IPL		TINP1 IPL	
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-10. Interrupt Priority Register 7 (IPR7)

See Programmer's Sheet on Appendix page B-29

8.9.8.1 Reserved—Bits 15–14

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.8.2 Timer Input Edge Interrupt Priority Level (TINP3 IPL)—Bits 13–12

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.8.3 Timer Overflow Interrupt Priority Level (TOVF3 IPL)—Bits 11–10

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.8.4 Timer Compare Interrupt Priority Level (TCMP3 IPL)—Bits 9–8

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1

- 11 = IRQ is priority level 2

8.9.8.5 Timer Input Edge Interrupt Priority Level (TINP2 IPL)—Bits 7–6

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.8.6 Timer Overflow Interrupt Priority Level (TOVF2 IPL)—Bits 5–4

These bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.8.7 Timer Compare Interrupt Priority Level (TCMP2 IPL)—Bits 3–2

These two bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0
- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.8.8 Timer Input Edge Interrupt Priority Level (TINP1 IPL)—Bits 1–0

These two bits are used to set the interrupt priority levels for this peripheral IRQ. This IRQ is limited to priorities 0-2. It is disabled by default.

- 00 = IRQ disabled by default
- 01 = IRQ is priority level 0

- 10 = IRQ is priority level 1
- 11 = IRQ is priority level 2

8.9.9 Vector Base Address Register (VBA)

Base + $8	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	VECTOR BASE ADDRESS												
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-11. Vector Base Address Register (VBA)

See Programmer's Sheet on Appendix page B-31

8.9.9.1 Reserved—Bits 15–13

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.9.2 Interrupt Vector Base Address (VECTOR_BASE_ADDR)—Bits 12–0

The value in this register is used as the upper 13 bits of the interrupt vector VBA[20:0]. The lower eight bits are determined based on the highest priority interrupt and are then appended onto VBA before presenting the full VBA to the core.

8.9.10 Fast Interrupt Match Registers 0 and 1 (FIM0, FIM1)

Base + $9	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	0	0	FAST INTERRUPT 0					
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-12. Fast Interrupt Match Register 0 (FIM0)

See Programmer's Sheet on Appendix page B-32

Base + $C	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	0	0	FAST INTERRUPT 1					
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-13. Fast Interrupt Match Register 1 (FIM1)

See Programmer's Sheet on Appendix page B-33

8.9.10.1 Reserved—Bits 15–6

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.10.2 Fast Interrupt Vector Number 0 (FAST INTERRUPT 0)—Bits 5–0

8.9.10.3 Fast Interrupt Vector Number 1 (FAST INTERRUPT 1)—Bits 5–0

These values are used to declare which two IRQs will be Fast Interrupts. Fast Interrupts vector directly to a service routine based on values in the Fast Interrupt Vector Address registers without having to go to a jump table first. IRQs used as fast interrupts *must* be set to priority level two. Unexpected results will occur if a fast interrupt vector is set to any other priority. Fast interrupts automatically become the highest priority level two interrupts regardless of their actual location in the interrupt table prior to being declared fast interrupts. Fast Interrupt 0 has priority over Fast Interrupt 1. To determine the vector number of each IRQ, please refer to **Table 8-2** later in this chapter.

Note: IRQs used as fast interrupts *must* be set to priority level two.

8.9.11 Fast Interrupt Vector Address Registers (FIVAL0, FIVAH0)

These registers are combined to form the two, 21-bit vector addresses for the fast interrupts defined in the FIVAL0 and FIVAH0 registers.

Base + $A	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	FAST INTERRUPT 0 VECTOR ADDRESS LOW															
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-14. Fast Interrupt Vector Address Low Register 0 (FIVAL0)

See Programmer's Sheet on Appendix page B-34

8.9.11.1 Fast Interrupt Vector Address Low 0—Bits 15–0

Lower 16 bits of vector address for fast interrupt zero.

Base + $B	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	0	0	0	FAST INTRRUPT 0 VECTOR ADDRESS HIGH				
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-15. Fast Interrupt Vector Address High Register 0 (FIVAH0)

See Programmer's Sheet on Appendix page B-34

8.9.11.2 Reserved—Bits 15–5

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.11.3 Fast Interrupt Vector Address High 0—Bits 4–0

Upper five bits of vector address for fast interrupt zero.

8.9.12 Fast Interrupt Vector Address Registers (FIVAL1, FIVAH1)

These registers are combined to form the two, 21-bit vector addresses for the fast interrupts defined in the FIVAL1 and FIVAL1 registers.

Base + $D	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	FAST INTERRUPT 1 VECTOR ADDRESS LOW															
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-16. Fast Interrupt Vector Address Low Register 1 (FIVAL1)

See Programmer's Sheet on Appendix page B-35

8.9.12.0.1 Fast Interrupt Vector Address Low 1 (FIVAL1)—Bits 15–0

Lower 16 bits of vector address for fast interrupt one.

Base + $E	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	0	0	0	FAST INTERRUPT 1 VECTOR ADDRESS HIGH				
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 8-17. Fast Interrupt Vector Address High 1 Register (FIVAH1)

See Programmer's Sheet on Appendix page B-35

8.9.12.1 Reserved—Bits 15–5

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.12.2 Fast Interrupt Vector Address High 1—Bits 4–0

Upper five bits of vector address for fast interrupt one.

8.9.13 IRQ Pending Registers (IRQP0, IRQP1, IRQP2, IRQP3)

These registers combine to represent the pending IRQs for interrupt vector numbers two through 64.

Base + $F	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	PENDING [16:1]															1
Write																
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 8-18. IRQ Pending Register 0 (IRQP0)

See Programmer's Sheet on Appendix page B-36

Base + $10	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	PENDING [32:17]															
Write																
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 8-19. IRQ Pending Register 1 (IRQP1)

See Programmer's Sheet on Appendix page B-36

Base + $11	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	PENDING [48:33]															
Write																
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 8-20. IRQ Pending Register 2 (IRQP2)

See Programmer's Sheet on Appendix page B-36

Base + $12	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	PENDING [64:49]															
Write																
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 8-21. IRQ Pending Register 3 (IRQP3)

See Programmer's Sheet on Appendix page B-36

8.9.13.1 IRQ Pending (PENDING)

- 0 = IRQ pending for this vector number
- 1 = No IRQ pending for this vector number

8.9.14 Interrupt Control Register (ICTL)

Base + $17	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	INT	IPLC		VN							INT_DIS	0	IRQB STATE	IRQA STATE	IRQB EDG	IRQAEDG
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0

Figure 8-22. Interrupt Control Register (ICTL)

See Programmer's Sheet on Appendix page B-37

8.9.14.1 Interrupt (INT)—Bit 15

This bit reflects the state of the interrupt to the core.

- 0 = An interrupt is being sent to the core
- 1 = No interrupt is being sent to the core

8.9.14.2 Interrupt Priority Level Core (IPLC)—Bit 14–13

These bits reflect the state of the new interrupt priority level bits being presented to the core at the time the last IRQ was taken. This field is only updated when the core jumps to a new interrupt service routine.

Note: Nested interrupts may cause this field to be updated before the original interrupt service routine can read it.

- 00 = Required nested exception priority levels are 0, 1, 2, or 3
- 01 = Required nested exception priority levels are 1, 2, or 3
- 10 = Required nested exception priority levels are 2 or 3
- 11 = Required nested exception priority level is 3

8.9.14.3 Vector Number (VN)—Bits 12–6

This field shows the Vector Number (VN), illustrated in **Table 8-2,** of the last IRQ taken. This field is only updated when the core jumps to a new interrupt service routine.

Note: Nested interrupts may cause this field to be updated before the original interrupt service routine can read it.

8.9.14.4 Interrupt Disable (INT_DIS)—Bit 5

This bit allows disable of all interrupts.

- All interrupts disabled
- Normal operation (default)

8.9.14.5 Reserved—Bit 4

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

8.9.14.6 State of $\overline{\text{IRQB}}$ (IRQB STATE)—Bit 3

This bit reflects the state of the external $\overline{\text{IRQB}}$ pin.

8.9.14.7 State of $\overline{\text{IRQA}}$ (IRQA STATE)—Bit 2

This bit reflects the state of the external $\overline{\text{IRQA}}$ pin.

8.9.14.8 $\overline{\text{IRQB}}$ Edge (IRQB EDG)—Bit 1

This bit controls whether the external $\overline{\text{IRQB}}$ interrupt is edge or level sensitive. During the Stop and Wait modes it is automatically level sensitive.

- $\overline{\text{IRQB}}$ interrupt is falling edge sensitive
- $\overline{\text{IRQB}}$ interrupt is low level sensitive (default)

8.9.14.9 $\overline{\text{IRQA}}$ Edge (IRQA EDG)—Bit 0

This bit controls whether the external $\overline{\text{IRQA}}$ interrupt is edge or level sensitive. During the Stop and Wait modes it is automatically level sensitive.

- $\overline{\text{IRQA}}$ interrupt is falling edge sensitive
- $\overline{\text{IRQA}}$ interrupt is low level sensitive (default)

8.10 Resets

8.10.1 Reset Handshake Timing

The ITCN provides the 56800E core with a reset vector address on the VAB pins whenever $\overline{\text{RST}}$ is asserted. The reset vector will be presented until the second rising clock edge after $\overline{\text{RST}}$ is released. The general timing is illustrated in the following diagram.

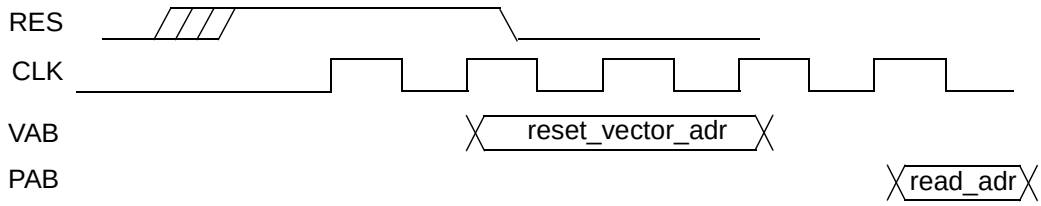


Figure 8-23. Reset Interface

8.10.2 ITCN After Reset

After reset, all of the ITCN registers are in their default states. This means all interrupts are disabled except the core IRQs with fixed priorities. Those core IRQs are:

- Illegal Instruction
- SW Interrupt 3
- HW stack overflow
- Misaligned long word access
- SW Interrupt 2
- SW Interrupt 1
- SW Interrupt 0
- SW Interrupt LP

These exceptions are enabled at their fixed priority levels.

8.11 Interrupts

8.11.1 Interrupt Handshake Timing

The control logic looks at the current interrupt processing level using the SR_REG[9:8] bits from the 56800E core and determines if an interrupt request of sufficient priority exists to assert the interrupt output to the core. Please see **Figure 8-24.** Upon asserting INT to the core, the interrupt controller also asserts new values for the IPIC_LEVEL pins. These pins indicate the priority level

required to interrupt this newly requested interrupt. The core will latch IPIC_LEVEL and it will be driven back to the interrupt controller as new values on the SR_REG[9:8] pins.

When the core recognizes the assertion of the interrupt pin, it will deassert PIC_EN. This tells the Interrupt Controller to drive VAB with the address corresponding to the highest priority interrupt request in order to start the interrupt service routine. When the core asserts the IACK signal, the Interrupt Controller will deassert the interrupt signal to the core. The controller will not reassert the interrupt signal until PIC_EN is asserted by the 56800E core.

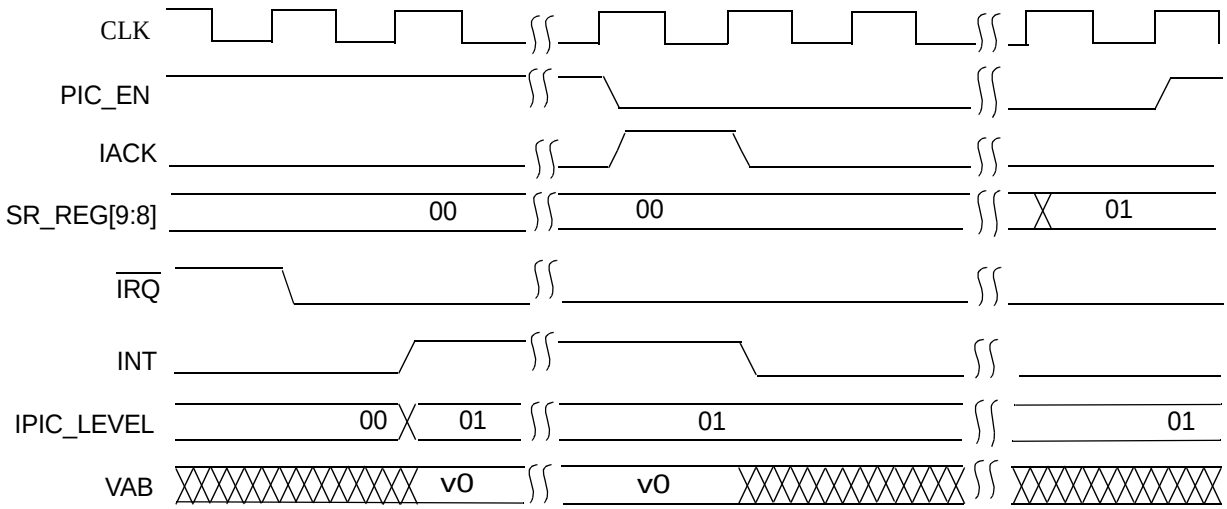


Figure 8-24. Interrupt Handshake Timing

8.11.2 Interrupt Nesting

Interrupt exceptions may be nested to allow an IRQ of higher priority than the current exception to be serviced. The following two tables define the nesting requirements for each priority level.

Table 8-4. Interrupt Mask Bit Definition

SR[9]	SR[8]	Exceptions Permitted	Exceptions Masked
0	0	Priorities 0, 1, 2, 3	None
0	1	Priorities 1, 2, 3	Priority 0
1	0	Priorities 2,3	Priorities 0, 1
1	1	Priority 3	Priorities 0, 1, 2

Table 8-5. Interrupt Priority Encoding

IPIC_LEVEL[1:0]	Current Interrupt Priority Level	Required Nested Exception Priority
00	No interrupt or SWILP	Priorities 0, 1, 2, 3
01	Priority 0	Priorities 1, 2, 3
10	Priority 1	Priorities 2, 3
11	Priorities 2 or 3	Priority 3

Chapter 9
Serial Communications Interface (SCI)

9.1 Introduction

This chapter describes the Serial Communications Interface (SCI) module. The module allows asynchronous serial communications with peripheral devices and other controllers.

9.2 Features

- Full-duplex or single wire operation
- Standard mark/space Non-Return-to-Zero (NRZ) format
- Thirteen-bit baud rate selection
- Programmable 8-bit or 9-bit data format
- Separately enabled transmitter and receiver
- Separate receiver and transmitter CPU interrupt requests
- Programmable polarity for transmitter and receiver
- Two receiver wake up methods:
  - Idle line
  - Address mark
- Interrupt-driven operation with seven flags:
  - Transmitter empty
  - Transmitter idle
  - Receiver full
  - Receiver overrun
  - Noise error
  - Framing error
  - Parity error
- Receiver framing error detection
- Hardware parity checking
- 1/16 bit-time noise detection

9.3 Block Diagram

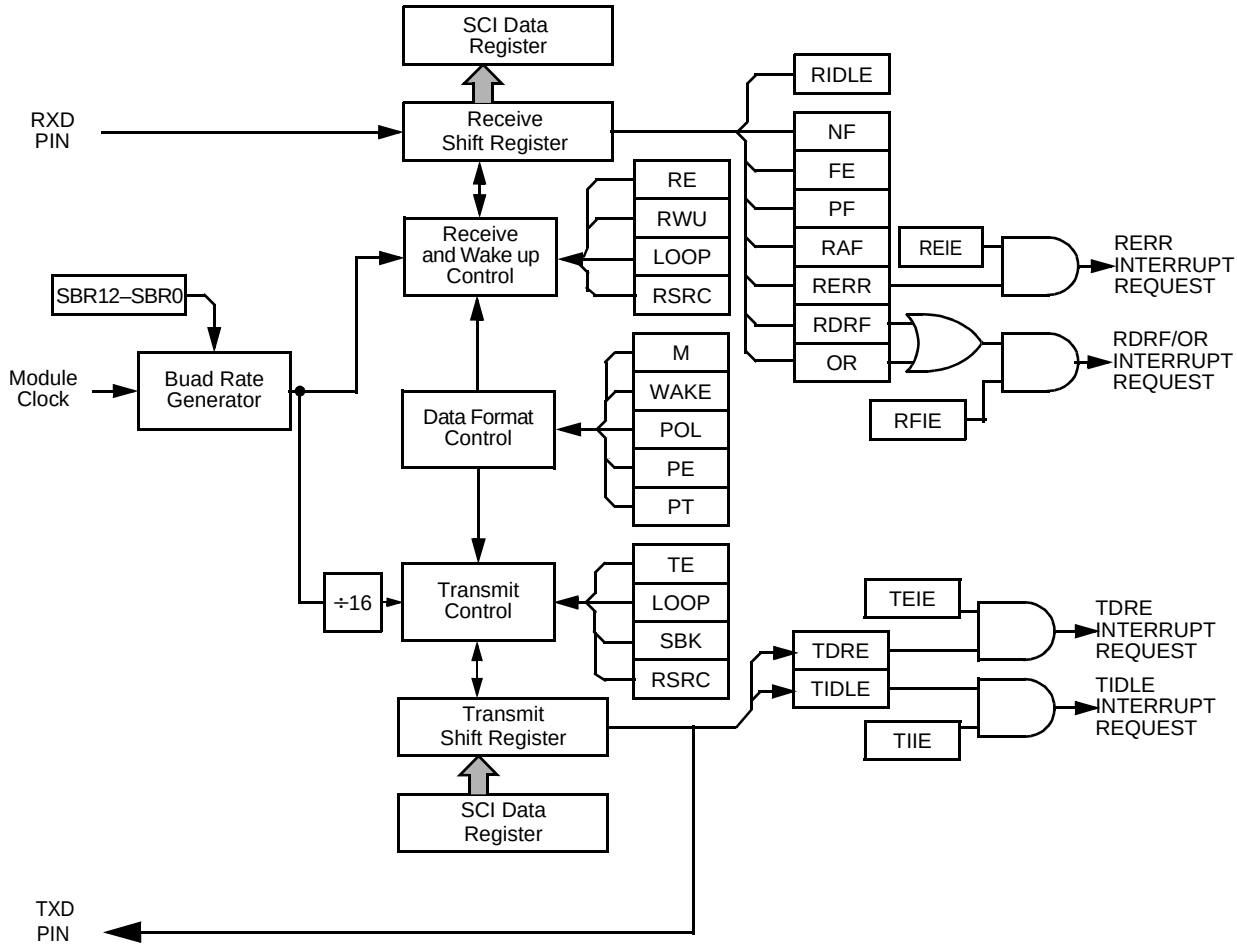


Figure 9-1. SCI Block Diagram

9.4 Signal Descriptions

9.4.1 Transmit Data (TXD) Pin

The Transmit Data Pin (TXD) is the SCI transmitter pin. TXD is available for general- purpose I/O when it is not configured for transmitter operation (TE = 0).

9.4.2 Receiver Data (RXD) Pin

The Receiver Data Pin (RXD) is the SCI receiver pin. RXD is available for general-purpose I/O when it is not configured for receiver operation (RE = 0).

The data in **Table 9-1** are external I/O signals for the chip interface.

Table 9-1. External I/O Signals

Signal Name	I/O Type	Description	Reset State
TXD	Output	Transmit Data Pin	1
RXD	Input	Receiver Data Pin	—

9.5 Functional Description

Figure 9-1explains the structure of the SCI module. The SCI allows full duplex, asynchronous, NRZ serial communication between the controller and remote devices, including other controllers. The SCI transmitter and receiver operate independently, although they use the same baud rate generator. The controller monitors the status of the SCI, writes the data to be transmitted, and processes received data.

When initializing the SCI, be sure to set the proper peripheral enable bits in the GPIO registers as well as any pull-up enables.

9.5.1 Data Frame Format

The SCI uses the standard Non-Return-to-Zero (NRZ) mark/space data frame format illustrated in **Figure 9-2.**

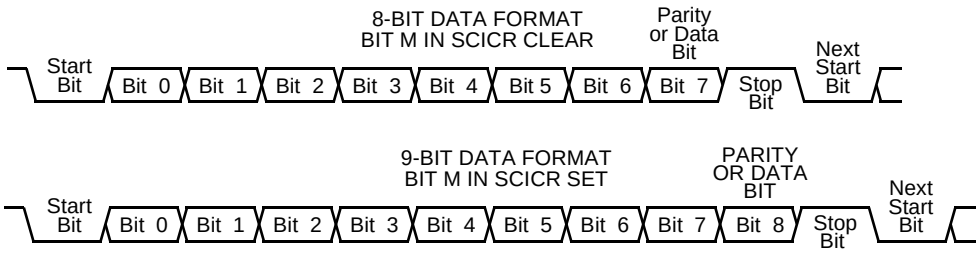


Figure 9-2. SCI Data Frame Formats

Each data character is contained in a frame including a Start bit, eight or nine Data bits, and a Stop bit. Clearing the M bit in the SCI Control Register (SCICR) configures the SCI for 8-bit data characters. A frame with eight Data bits has a total of 10 bits.

Table 9-2. Example 8-Bit Data Frame Formats

Start Bit	Data Bits	Address Bit	Parity Bit	Stop Bit
1	8	0	0	1
1	7	0	1	1
1	7	1[1]	0	1

1. The address bit identifies the frame as an address character. Please see Section 9.5.4.8, Receiver Wake Up

Setting the M bit configures the SCI for 9-bit data characters. A frame with nine Data bits has a total of 11 bits.

Table 9-3. Example 9-Bit Data Frame Formats

Start Bit	Data Bits	Address Bit	Parity Bit	Stop Bit
1	9	0	0	1
1	8	0	0	2
1	8	0	1	1
1	8	1[1]	0	1

1. The address bit identifies the frame as an address character. Please see Section 9.5.4.8, Receiver Wake Up

9.5.2 Baud Rate Generation

A 13-bit modulus counter in the baud rate generator derives the baud rate for both the receiver and the transmitter. A value of one to 8191 written to the SBR bits determines the module clock divisor. A value of 0 disables the baud rate generator. The SBR bits are bits 12:0 of the SCI Baud Rate (SCIBR) register. The baud rate clock is synchronized with the bus clock, driving the receiver. The baud rate clock, divided by 16, drives the transmitter. The receiver has an acquisition rate of 16 samples per bit time.

Baud rate generation is subject to two sources of error:

1. Integer division of the module clock may not give the exact target frequency.
2. Synchronization with the bus clock can cause phase shift.

Table 9-4 lists examples of achieving target baud rates with a module clock frequency of 60MHz.

Table 9-4. Example Baud Rates (Module Clock = 60Mhz)

SBR Bits	Receiver Clock (Hz)	Transmitter Clock (Hz)	Target Baud Rate	Error (%)
98	612,320	38,270	38,400	0.34
195	307,692	19,230.8	19,200	-0.15
391	157,734	9.591	9,600	-0.10
781	76,824	4,801.5	4,800	0.03
1562	38,412	2,400.8	2,400	0.03
3125	19,200	1,200	1,200	0.00
6250	9,600	600.0	600	0.00

Note: Maximum baud rate is module clock rate divided by 16. System overhead may preclude processing the data at this speed.

9.5.3 Transmitter Block Diagram

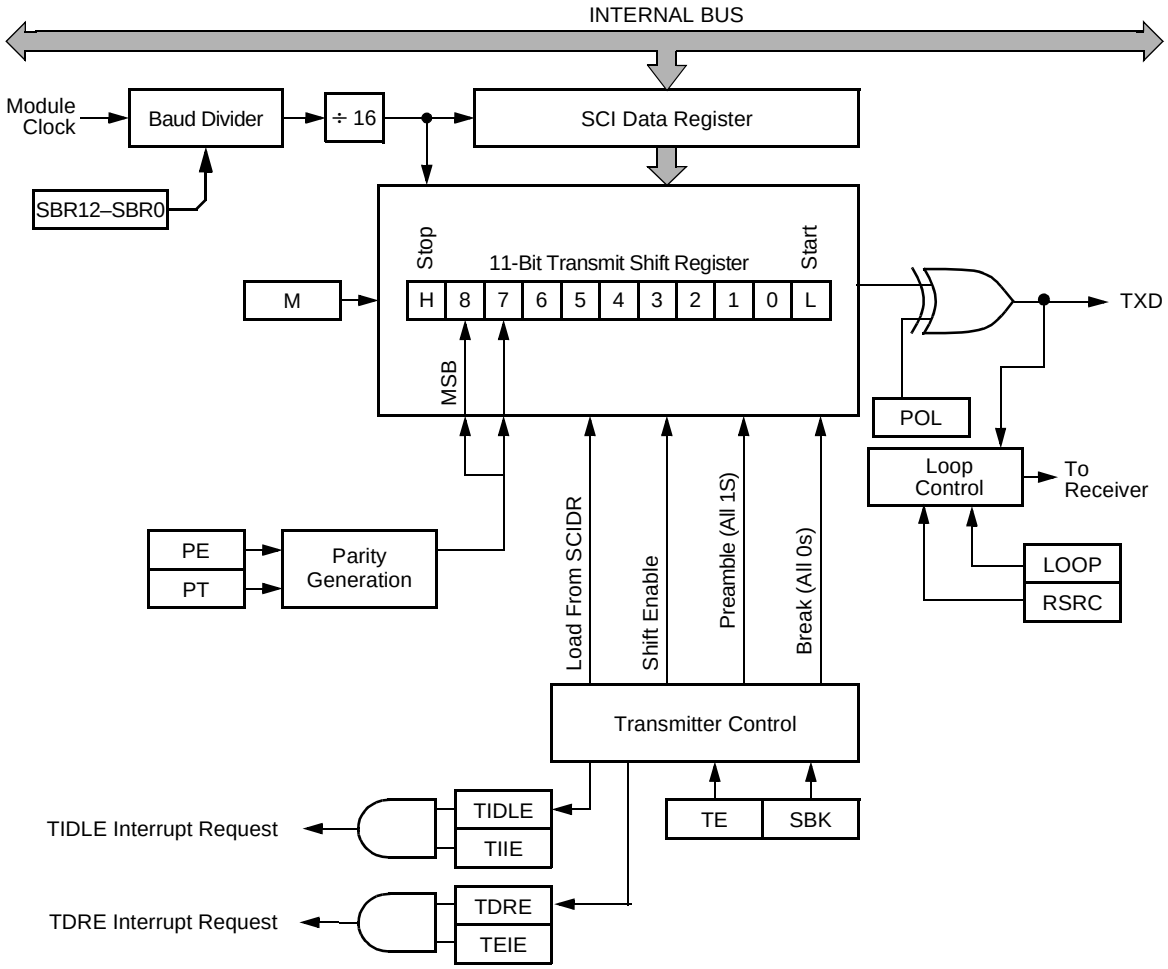


Figure 9-3. SCI Transmitter Block Diagram

9.5.3.1 Character Length

The SCI transmitter can accommodate either 8- or 9-bit data characters. The state of the M bit in the SCI Control Register (SCICR) determines the length of data characters.

9.5.3.2 Character Transmission

During an SCI transmission, the Transmit Shift Register shifts a frame out to the TXD pin. The data is writen through the SCI data register.

To initiate a SCI transmission:

1. Enable the transmitter by writing a Logic 1 to the Transmitter Enable (TE) bit in the SCI Control Register (SCICR).
2. Clear the Transmit Data Register Empty (TDRE) flag by first reading the SCI Status Register (SCISR) and then writing to the SCI Data Register (SCIDR).
3. Repeat step two above for each subsequent transmission.

Modifying the TE bit from zero to a one automatically loads the Transmit Shift Register with a preamble of 10 Logic 1s (if M = 0) or 11 Logic 1s (if M = 1). After the preamble shifts out, control logic automatically transfers the data from the SCI Data Register into the Transmit Shift Register. A Logic 0 Start bit automatically goes into the least significant bit position of the Transmit Shift Register. A Logic 1 Stop bit goes into the Most Significant Bit (MSB) position of the frame.

Hardware supports odd or even parity. When parity is enabled, the MSB of the data character is replaced by the parity bit.

The Transmit Data Register Empty (TDRE) flag in the SCI Status Register (SCISR) becomes set when the SCI Data Register transfers a character to the Transmit Shift Register. The TDRE flag indicates when the SCI Data Register can accept new data from the internal data bus. If the Transmitter Empty Interrupt Enable (TEIE) bit in the SCI Control Register (SCICR) is also set, the TDRE flag generates a transmitter interrupt request.

When the Transmit Shift Register is not transmitting a frame and TE = 1, the TXD pin goes to the idle condition, Logic 1. If at any time software clears the TE bit in the SCI Control Register (SCICR), the transmitter relinquishes control of the port I/O pin upon completion of the current transmission causing the TXD pin to go to a HighZ state.

If software clears TE while a transmission is in progress (TIDLE = 0), the frame in the Transmit Shift Register continues to shift out. Then transmission stops even if there is data pending in the SCI Data Register. To avoid accidentally cutting off the last frame in a message, always wait for TDRE to go high after the last frame before clearing TE.

To separate messages with preambles with minimum idle line time, use this sequence between messages:

1. Write the last character of the first message to SCIDR.
2. Wait for the TDRE flag to go high, indicating the transfer of the last frame to the Transmit Shift Register.
3. Queue a preamble by clearing and then setting the TE bit.
4. Write the first character of the second message to SCIDR.

9.5.3.3 Break Characters

Writing Logic 1 to the Send Break (SBK) bit in the SCI Control Register (SCICR) loads the Transmit Shift Register with a break character. A break character contains all logic zeros and has no Start, Stop, or Parity bit. Break character length depends on the M bit in the SCI Control Register (SCICR). As long as SBK is at Logic 1, transmitter logic continuously loads break characters into the Transmit Shift Register. After software clears the SBK bit, the Shift register finishes transmitting the last break character and then transmits at least one Logic 1. The automatic Logic 1 at the end of the last break character guarantees the recognition of the Start bit of the next frame.

The SCI recognizes a break character when a start bit is followed by eight or nine logic zero data bits and a logic zero where the Stop bit should be. Receiving a break character has these effects on SCI registers:

- Sets the Framing Error flag (FE)
- Sets the Receive Data Register Full flag (RDRF)
- Clears the SCI Data Register (SCIDR)
- May set the Overrun (OR) flag, Noise Flag (NF), Parity Error (PE) flag, or the Receiver Active Flag (RAF). Please see the SCI Status Register in **Section 9.8.3.**

9.5.3.4 Preambles

A preamble contains all logic ones and has no Start, Stop, or Parity bit. A preamble length depends on the M bit in the SCI Control Register (SCICR). The preamble is a synchronizing mechanism that begins the first transmission initiated after modifying the TE bit from zero to one.

If the TE bit is cleared during a transmission, the TXD pin becomes idle after completion of the transmission in progress. Clearing and then setting the TE bit during a transmission queues a preamble to be sent after the frame currently being transmitted.

Note: Toggle the TE bit for a queued preamble when the TDRE flag becomes set and immediately before writing the next character to the SCI Data Register.

When queueing a preamble, return the TE bit to Logic 1 before the Stop bit of the current frame shifts out to the TXD pin. Setting TE after the Stop bit appears on TXD causes data previously written to the SCI Data Register to be lost.

9.5.3.5 Receiver

Figure 9-4 explains the block diagram of the SCI receiver with detailed discussion of the receiver function in the following paragraphs.

9.5.4 Receiver Block Diagram

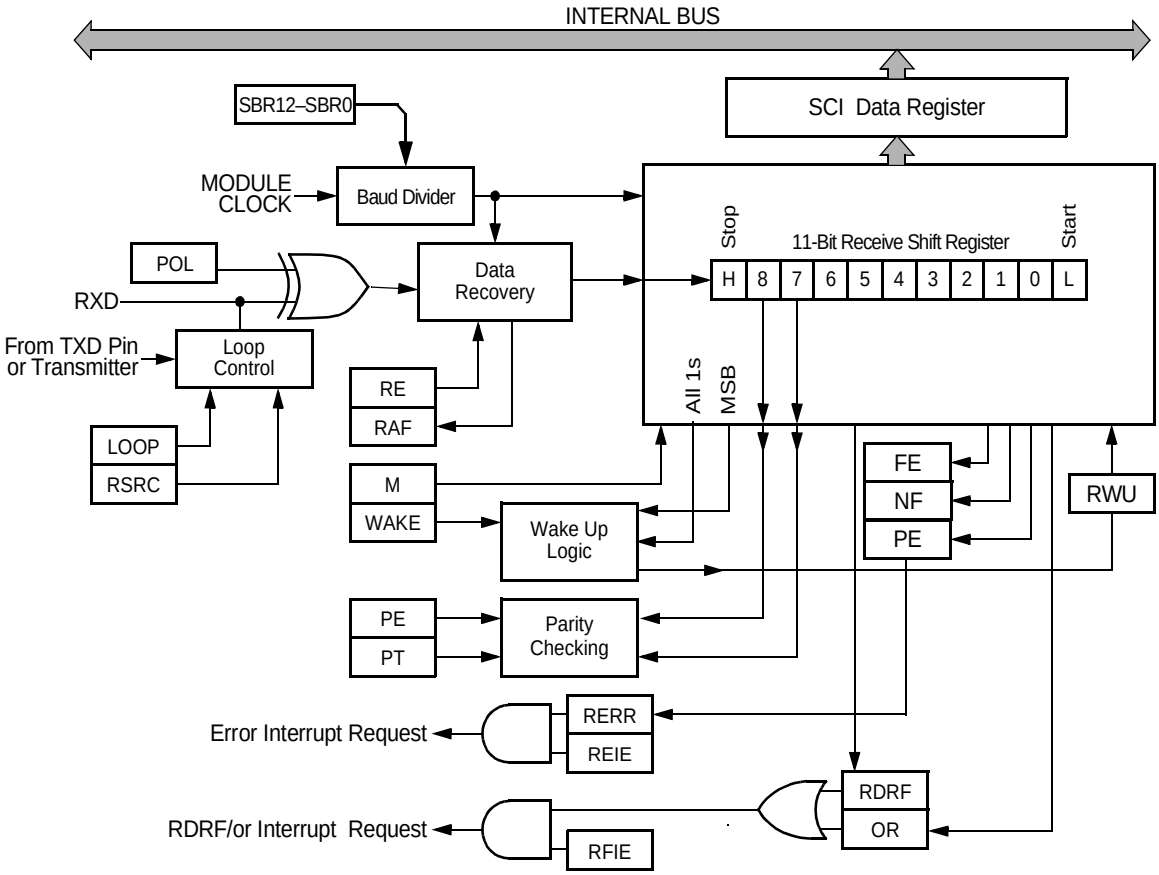


Figure 9-4. SCI Receiver Block Diagram

9.5.4.1 Character Length

The SCI receiver can accommodate either 8- or 9-bit data characters. The state of the M bit in the SCI Control Register (SCICR) determines the length of data characters.

9.5.4.2 Character Reception

During an SCI reception, the Receive Shift Register shifts a frame in from the RXD pin. The data is read from the SCI Data Register (SCIDR).

After a complete frame shifts into the Receive Shift Register, the data portion of the frame transfers to the SCI Data Register. The Receive Data Register Full (RDRF) flag in the SCI Status Register (SCISR) becomes set, indicating the received character can be read. If the Receive Full Interrupt Enable (RFIE) bit in the SCI Control Register (SCICR) is also set, the RDRF flag generates an RDRF interrupt request.

9.5.4.3 Data Sampling

The receiver samples the RXD pin at the RT clock rate. The RT clock is an internal signal with a frequency 16 times the baud rate. To adjust for baud rate mismatch, the RT clock illustrated in **Figure 9-5** is resynchronized:

- After every start bit
- After the receiver detects a data bit change from Logic 1 to Logic 0 (after the majority of data bit samples at RT8, RT9, and RT10 returns a valid Logic 1 and the majority of the next RT8, RT9, and RT10 samples returns a valid Logic 0)

To locate the start bit, data recovery logic does an asynchronous search for a Logic 0 preceded by three logic ones. When the falling edge of a possible start bit occurs, the RT clock begins to count to 16.

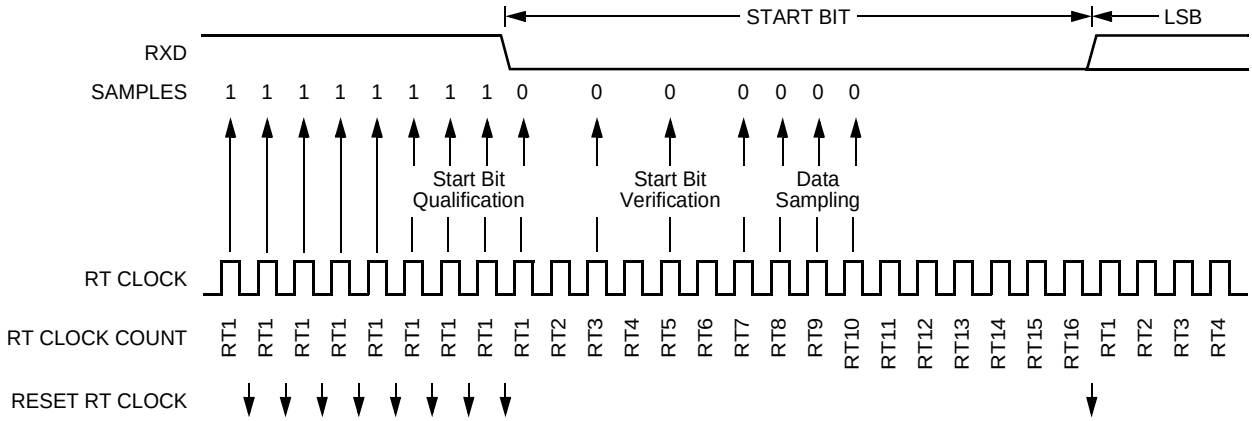

START BIT
LSB
RXD
SAMPLES
1 1 1 1 1 1 1 1 0 0 0 0 0 0 0
Start Bit Qualification
Start Bit Verification
Data Sampling
RT CLOCK
RT CLOCK COUNT
RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT2 RT3 RT4 RT5 RT6 RT7 RT8 RT9 RT10 RT11 RT12 RT13 RT14 RT15 RT16 RT1 RT2 RT3 RT4
RESET RT CLOCK

Figure 9-5. Receiver Data Sampling

To verify the start bit and to detect noise, data recovery logic takes samples at RT3, RT5, and RT7. **Table 9-5** summarizes the results of the Start bit verification samples. If the start bit verification is not successful, the RT clock is reset and a new search for a start bit begins.

Table 9-5. Start Bit Verification

RT3, RT5, and RT7 Samples	Start Bit Verification	Noise Flag
000	Yes	0
001	Yes	1
010	Yes	1
011	No	0
100	Yes	1
101	No	0
110	No	0
111	No	0

If start bit verification is not successful, the RT clock is reset and a new search for a start bit begins.

To determine the value of a data bit and to detect noise, recovery logic takes samples at RT8, RT9, and RT10. **Table 9-6** summarizes the results of the data bit samples.

Table 9-6. Data Bit Recovery

RT8, RT9, and RT10 Samples	Data Bit Determination	Noise Flag
000	0	0
001	0	1
010	0	1
011	1	1
100	0	1
101	1	1
110	1	1
111	1	0

Note: The RT8, RT9, and RT10 samples do not affect start bit verification. If any or all of the RT8, RT9, and RT10 Start bit samples are logic ones following a successful start bit verification, the Noise Flag (NF) is set and the receiver assumes that the bit is a Start bit (Logic 0).

To verify a Stop bit and to detect noise, recovery logic takes samples at RT8, RT9, and RT10. **Table 9-7** summarizes the results of the Stop bit samples.

Table 9-7. Stop Bit Recovery

RT8, RT9, and RT10 Samples	Framing Error Flag	Noise Flag
000	1	0
001	1	1
010	1	1
011	0	1
100	1	1
101	0	1
110	0	1
111	0	0

Figure 9-6 illustrates the verification samples RT3 and RT5 determine the first low detected was noise and not the beginning of a start bit. The RT clock is reset and the start bit search begins again. The noise flag is not set because the noise occurred before the start bit was found.

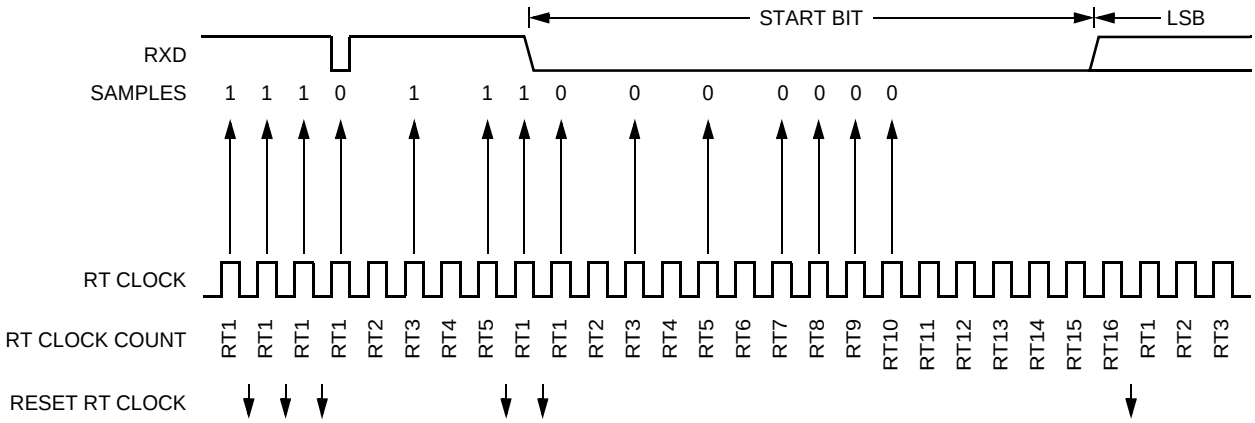

START BIT
LSB
RXD
SAMPLES
1 1 1 0 1 1 1 0 0 0 0 0 0 0
RT CLOCK
RT CLOCK COUNT
RT1 RT1 RT1 RT1 RT2 RT3 RT4 RT5 RT1 RT1 RT2 RT3 RT4 RT5 RT6 RT7 RT8 RT9 RT10 RT11 RT12 RT13 RT14 RT15 RT16 RT1 RT2 RT3
RESET RT CLOCK

Figure 9-6. Start Bit Search Example 1

Figure 9-7 shows noise is perceived as the beginning of a start bit although the verification sample at RT3 is high. The RT3 sample sets the noise flag. Although the perceived bit time is misaligned, the data samples RT8, RT9, and RT10 are within the bit time and data recovery is successful.

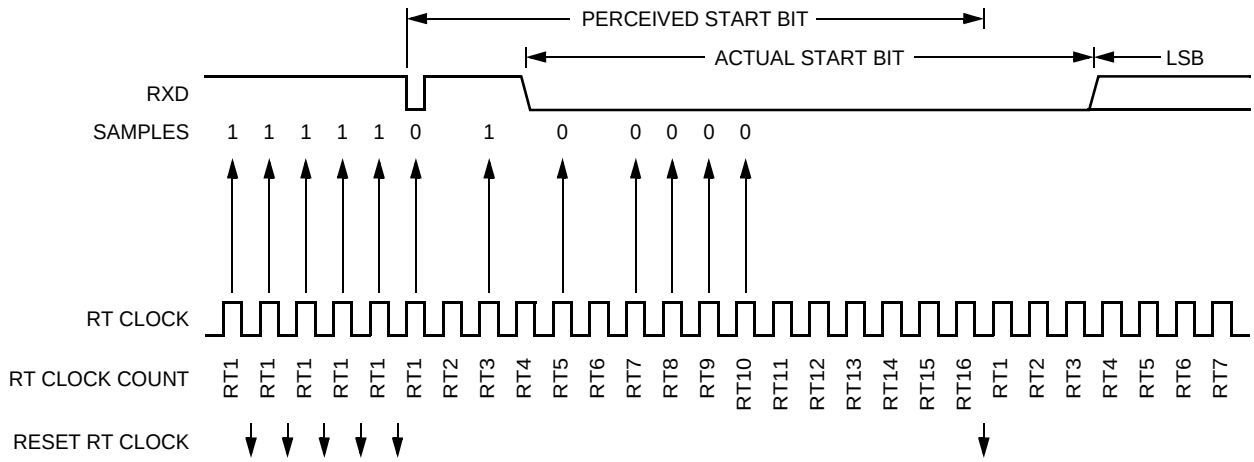

PERCEIVED START BIT
ACTUAL START BIT
LSB
RXD
SAMPLES
1 1 1 1 1 0 1 0 0 0 0 0
RT CLOCK
RT CLOCK COUNT
RT1 RT1 RT1 RT1 RT1 RT1 RT2 RT3 RT4 RT5 RT6 RT7 RT8 RT9 RT10 RT11 RT12 RT13 RT14 RT15 RT16 RT1 RT2 RT3 RT4 RT5 RT6 RT7
RESET RT CLOCK

Figure 9-7. Start Bit Search Example 2

Figure 9-8 illustrates a large burst of noise is perceived as the beginning of a start bit, although the test sample at RT5 is high. The RT5 sample sets the noise flag. Although this is a worst-case misalignment of perceived bit time, the data samples RT8, RT9, and RT10 are within the bit time and data recovery is successful.

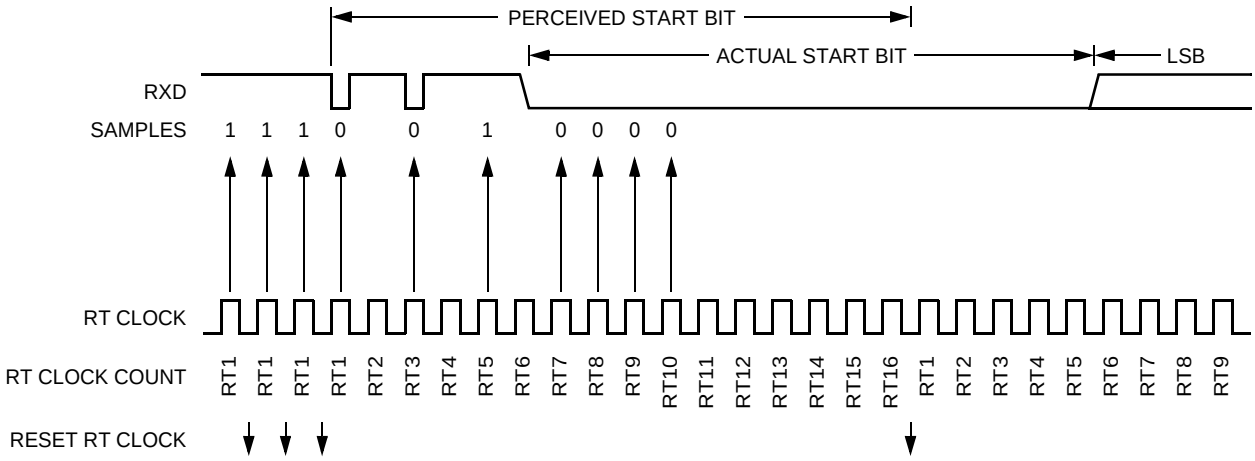

PERCEIVED START BIT
ACTUAL START BIT
LSB
RXD
SAMPLES
1 1 1 0 0 1 0 0 0 0
RT CLOCK
RT CLOCK COUNT
RT1 RT1 RT1 RT1 RT2 RT3 RT4 RT5 RT6 RT7 RT8 RT9 RT10 RT11 RT12 RT13 RT14 RT15 RT16 RT1 RT2 RT3 RT4 RT5 RT6 RT7 RT8 RT9
RESET RT CLOCK

Figure 9-8. Start Bit Search Example 3

Figure 9-9 illustrates the effect of noise early in the start bit time. Although this noise does not affect proper synchronization with the start bit time, it does set the noise flag.

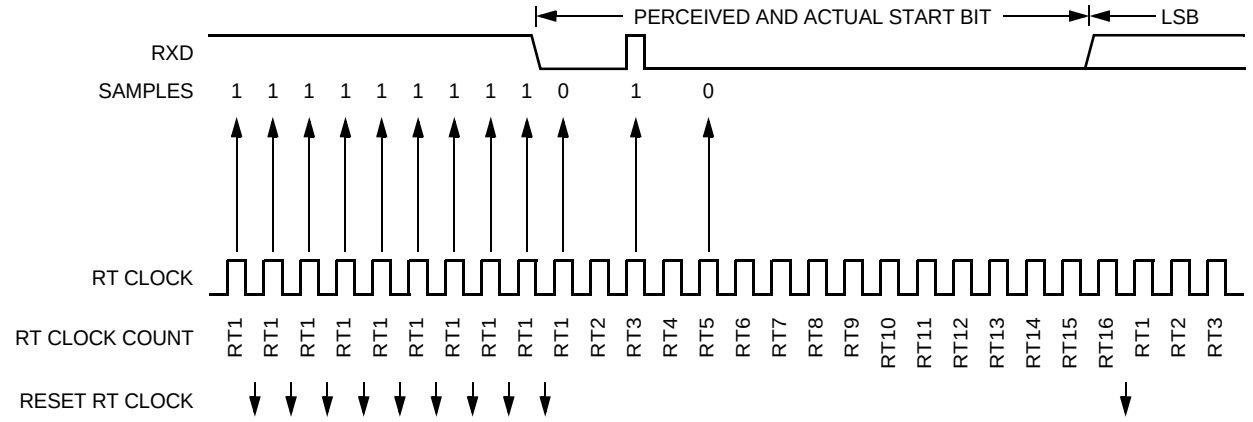

PERCEIVED AND ACTUAL START BIT
LSB
RXD
SAMPLES
1 1 1 1 1 1 1 1 1 0 1 0
RT CLOCK
RT CLOCK COUNT
RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT2 RT3 RT4 RT5 RT6 RT7 RT8 RT9 RT10 RT11 RT12 RT13 RT14 RT15 RT16 RT1 RT2 RT3
RESET RT CLOCK

Figure 9-9. Start Bit Search Example 4

Figure 9-10 demonstrates a burst of noise near the beginning of the start bit, resetting the RT clock. The sample after the reset is low but is not preceded by three high samples qualifying as a falling edge. Depending on the timing of the start bit search and on the data, the frame may be missed entirely or it may set the framing error flag.

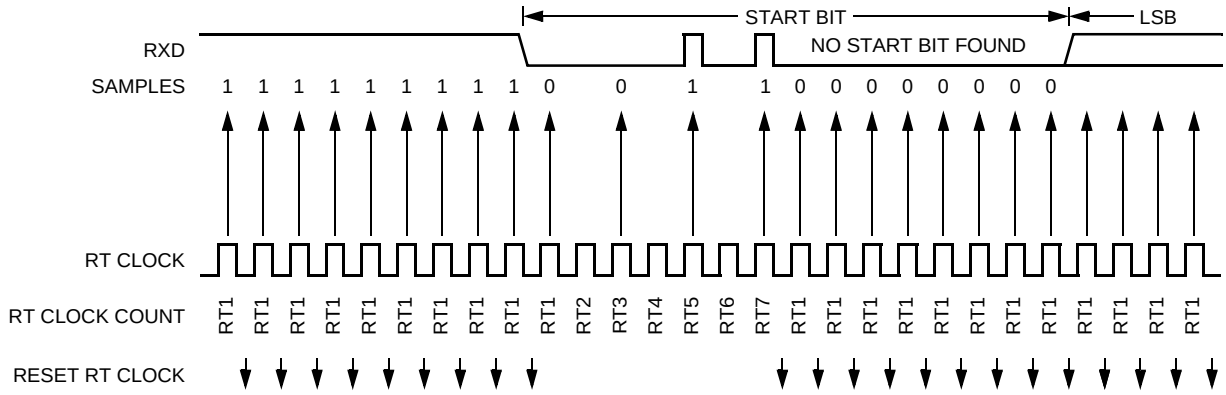

START BIT
LSB
RXD
NO START BIT FOUND
SAMPLES
1 1 1 1 1 1 1 1 1 0 0 1 1 0 0 0 0 0 0 0 0
RT CLOCK
RT CLOCK COUNT
RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT2 RT3 RT4 RT5 RT6 RT7 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1
RESET RT CLOCK

Figure 9-10. Start Bit Search Example 5

Figure 9-11 shows a noise burst makes the majority of data samples RT8, RT9, and RT10 high. This sets the noise flag but does not reset the RT clock. In start bits only, the RT8, RT9, and RT10 data samples are ignored.

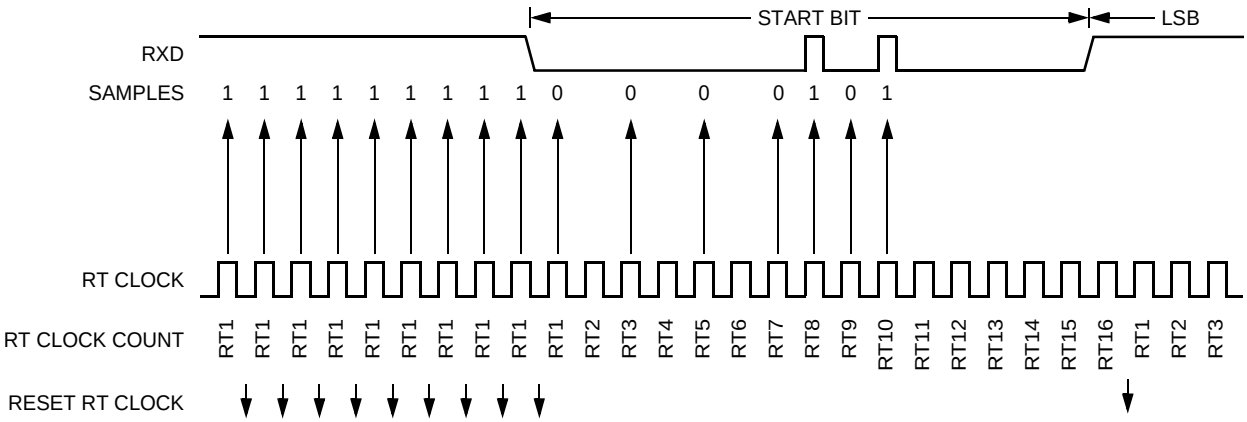

START BIT
LSB
RXD
SAMPLES
1 1 1 1 1 1 1 1 1 0 0 0 0 1 0 1
RT CLOCK
RT CLOCK COUNT
RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT1 RT2 RT3 RT4 RT5 RT6 RT7 RT8 RT9 RT10 RT11 RT12 RT13 RT14 RT15 RT16 RT1 RT2 RT3
RESET RT CLOCK

Figure 9-11. Start Bit Search Example 6

9.5.4.4 Framing Errors

If the data recovery logic does not detect a Logic 1 where the Stop bit should be in an incoming frame, it sets the Framing Error (FE) flag in the SCI Status Register (SCISR). A break character also sets the FE flag because a break character has no Stop bit. The FE flag is set at the same time that the RDRF flag is set. The FE flag inhibits further data reception until it is cleared.

9.5.4.5 Baud Rate Tolerance

A transmitting device may be operating at a baud rate below or above the receiver baud rate. Accumulated bit time misalignment can cause one of the three Stop bit data samples to fall

outside the actual Stop bit. Then a noise error occurs. If more than one of the samples is outside the Stop bit, a framing error occurs. In most applications, the baud rate tolerance is much more than the degree of misalignment that is likely to occur.

As the receiver samples an incoming frame, it re synchronizes the RT clock on any valid falling edge within the frame. Re-synchronization within frames corrects misalignments between transmitter bit times and receiver bit times.

9.5.4.6 Slow Data Tolerance

Figure 9-12 explains how much a slow received frame can be misaligned without causing a noise error or a framing error. The slow Stop bit begins at RT8 instead of RT1, but it arrives in time for the Stop bit data samples at RT8, RT9, and RT10.

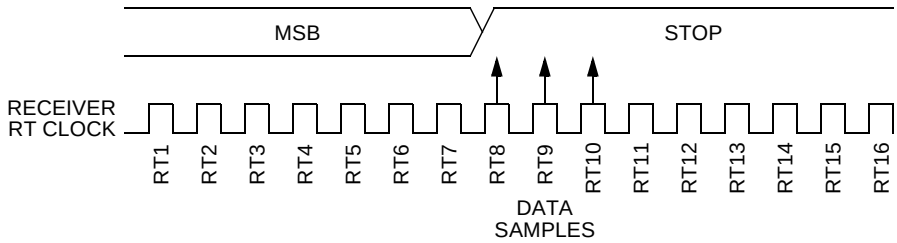


Figure 9-12. Slow Data

For an 8-bit data character, data sampling of the Stop bit takes the receiver 9-bit × 16 RT cycles + 10 RT cycles = 154 RT cycles.

With the misaligned character shown in **Figure 9-12**, the receiver counts 154 RT cycles at the point when the count of the transmitting device is 9-bit × 16 RT cycles + 3 RT cycles = 147 RT cycles.

The maximum percent difference between the receiver count and the transmitter count of a slow 8-bit data character with no errors is:

$$\left|\frac{154 - 147}{154}\right| \times 100 = 4.54\%$$

For a 9-bit data character, data sampling of the Stop bit takes the receiver 10-bit × 16 RT cycles + 10 RT cycles = 170 RT cycles.

With the misaligned character shown in Figure **Table 9-12,** the receiver counts 170 RT cycles at the point when the count of the transmitting device is 10 bit × 16 RT cycles + 3 RT cycles = 163 RT cycles.

The maximum percent difference between the receiver count and the transmitter count of a slow 9-bit character with no errors is:

$$\left|\frac{170 - 163}{170}\right| \times 100 = 4.12\%$$

9.5.4.7 Fast Data Tolerance

Figure 9-13 demonstrates how much a fast received frame can be misaligned without causing a noise error or a framing error. The fast Stop bit ends at RT10 instead of RT16 but it is still sampled at RT8, RT9, and RT10.

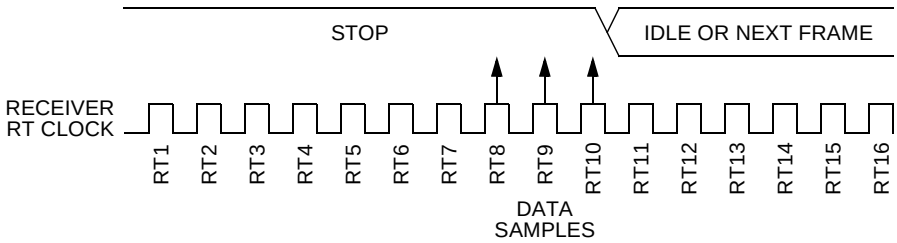


Figure 9-13. Fast Data

For an 8-bit data character, data sampling of the Stop bit takes the receiver 9-bit × 16 RT cycles + 10 RT cycles = 154 RT cycles.

With the misaligned character shown in **Figure 9-13,** the receiver counts 154 RT cycles at the point when the count of the transmitting device is 10 bit × 16 RT cycles = 160 RT cycles.

The maximum percent difference between the receiver count and the transmitter count of a fast 8-bit character with no errors is:

$$\left|\frac{154 - 160}{154}\right| \times 100 = 3.90\%$$

For a 9-bit data character, data sampling of the Stop bit takes the receiver 10 bit × 16 RT cycles + 10 RT cycles = 170 RT cycles.

With the misaligned character shown in **Figure 9-13,** the receiver counts 170 RT cycles at the point when the count of the transmitting device is 11 bit × 16 RT cycles = 176 RT cycles.

The maximum percent difference between the receiver count and the transmitter count of a fast 9-bit character with no errors is:

$$\left|\frac{170 - 176}{170}\right| \times 100 \;=\; 3.53\%$$

9.5.4.8 Receiver Wake Up

In order for the SCI to ignore transmissions intended only for other receivers in multiple-receiver systems, the receiver can be put into a standby state. Setting the Receiver Wake Up (RWU) bit in the SCI Control Register (SCICR) puts the receiver into a standby state while receiver interrupts are disabled.

The transmitting device can address messages to selected receivers by including addressing information in the initial frame or frames of each message.

The WAKE bit in the SCI Control Register (SCICR) determines how the SCI is brought out of the standby state to process an incoming message. The WAKE bit enables either idle line wake up or address mark wake up:

- Idle Input Line Wake Up (WAKE = 0)—In this wake up method, an idle condition on the RXD pin clears the RWU bit and wakes up the SCI. The initial frame or frames of every message contains addressing information. All receivers evaluate the addressing information and receivers the message addresses, process the following frames. Any receiver a message does not address can set its RWU bit and return to the standby state. The RWU bit remains set and the receiver remains on standby until another preamble appears on the RXD pin.

  Idle line wake up requires messages be separated by at least one preamble. No message contains preambles.

  The receiver-waking preamble does not set the receiver Idle (IDLE) bit or the Receive Data Register Full (RDRF) flag.
- Address Mark Wake up (WAKE = 1)—In this wake up method, a Logic 1 in the MSB position of a frame clears the RWU bit and wakes up the SCI. The Logic 1 in the MSB position marks a frame as an address frame that contains addressing information. All receivers evaluate the addressing information, and the receivers for which the message is addressed process the frames that follow. Any receiver for which a message is not addressed can set its RWU bit and return to the standby state. The RWU bit remains set and the receiver remains on standby until another address frame appears on the RXD pin.

The Logic 1 MSB of an address frame clears the receiver’s RWU bit before the Stop bit is received and sets the RDRF flag.

Address mark wake up allows messages to contain preambles but requires the MSB to be reserved for use in address frames.

Note: With the WAKE bit clear, setting the RWU bit after the RXD pin has been idle can cause the receiver to wake up immediately.

9.5.5 Single-Wire Operation

Normally, the SCI uses two pins for transmitting and receiving. In the single-wire operation, the RXD pin is disconnected from the SCI and is available as a General Purpose I/O (GPIO) pin. The SCI uses the TXD pin for both receiving and transmitting.

Setting the TE bit in the SCI Control Register (SCICR) configures TXD as the output for transmitted data. Clearing the TE bit configures TXD as the input for received data.

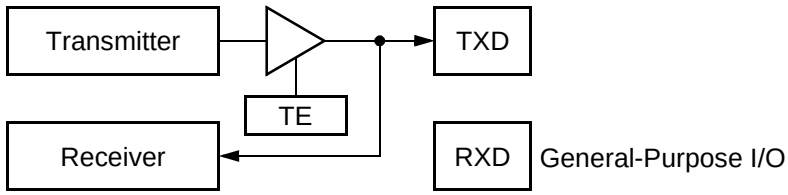


Figure 9-14. Single-Wire Operation (LOOP = 1, RSRC = 1)

Enable single-wire operation by setting the LOOP bit and the Receiver Source (RSRC) bit in the SCI Control Register (SCICR). Setting the LOOP bit disables the path from the RXD pin to the receiver. Setting the RSRC bit connects the receiver input to the output of the TXD pin driver.

9.5.6 Loop Operation

In Loop operation the transmitter output goes to the receiver input. The RXD pin is disconnected from the SCI and is available as a GPIO pin.

Setting the TE bit in the SCI Control Register (SCICR) connects the transmitter output to the TXD pin. Clearing the TE bit disconnects the transmitter output from the TXD pin.

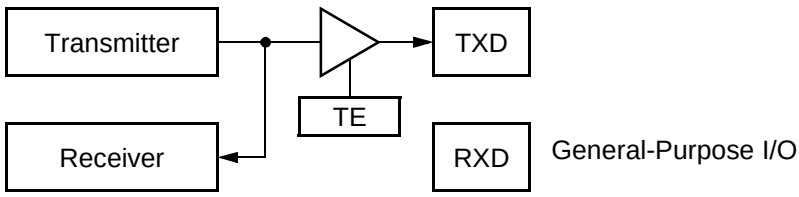


Figure 9-15. Loop Operation (LOOP = 1, RSRC = 0)

Enable Loop operation by setting the LOOP bit and clearing the RSRC bit in the SCI Control Register (SCICR). Setting the LOOP bit disables the path from the RXD pin to the receiver. Clearing the RSRC bit connects the transmitter output to the receiver input. Both the transmitter and receiver must be enabled (TE = 1 and RE = 1).

9.6 Low Power Modes

9.6.1 Run Mode

Clearing the Transmitter Enable (TE) or Receiver Enable (RE) bits (X or RE) in the SCI Control Register (SCICR), reduces power consumption in the Run mode. SCI registers are still accessible when TE or RE is cleared, but clocks to the core of the SCI are disabled.

9.6.2 Wait Mode

SCI operation in the Wait mode depends on the state of the SWAI bit in the SCI Control Register (SCICR).

- If SWAI is clear, the SCI operates normally when the Central Processing Unit (CPU) is in the Wait mode.
- If SWAI is set, SCI clock generation ceases and the SCI module enters a power-conservation state when the CPU is in the Wait mode. In this condition, SCI registers are not accessible. Setting SWAI does not affect the state of the Receiver Enable (RE) bit or the Transmitter Enable (TE) bit.

  If SWAI is set, any transmission or reception in progress stops at the Wait mode entry. The transmission or reception resumes when either an internal or external interrupt brings the device out of the Wait mode. Exiting the Wait mode by reset aborts any transmission or reception in progress and resets the SCI.

9.6.3 Stop Mode

The SCI is inactive in the Stop mode for reduced power consumption. The STOP instruction does not affect SCI register states. SCI operation resumes after an external interrupt brings the CPU out of the Stop mode. Exiting the Stop mode by reset aborts any transmission or reception in progress and resets the SCI.

9.6.4 Wait Mode Recovery

Any enabled SCI interrupt request can bring the CPU out of the Wait mode.

9.7 Module Memory Map

There are four accessible registers on the SCI outlined in **Table 9-8.**

Table 9-8. SCI Module Memory Map (SCI_BASE = $1FFFE0)

Address Offset	Register Acronym	Register Name	Access Type	Chapter Location
$1FFFE0	SCIBR	Baud Rate Register	Read/Write	Section 9.8.1
$1FFFE1	SCICR	Control Register	Read/Write	Section 9.8.2
$1FFFE3	SCISR	Status Register	*Read-Only*	Section 9.8.3
$1FFFE4	SCIDR	Data Register	Read/Write	Section 9.8.4

Add. Offset	Register Name		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$0	SCIBR	R	0	0	0	SBR												
		W																
$1	SCICR	R	LOOP	SWAI	RSRC	M	WAKE	POL	PE	PT	TEIE	TIIE	RFIE	REIE	TE	RE	RWU	SBK
		W																
$3	SCISR	R	TDRE	TIDLE	RDRF	RIDLE	OR	NF	FE	PF	0	0	0	0	0	0	0	RAF
		W																
$4	SCIDR	R	0	0	0	0	0	0	0	RECEIVE DATA								
		W								TRANSMIT DATA								

R 0 Read as 0
W Reserved

Figure 9-16. SCI Register Map Summary

9.8 Register Descriptions (SCI_BASE = $1FFFE0)

9.8.1 SCI Baud Rate (SCIBR)

This register can be read at anytime. Bits 12 through zero can be written at any time, but bits 15 through 13 are reserved and can be modified only in special modes.

Base + $0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	SBR												
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 9-17. SCI Baud Rate Register (SCIBR)

See Programmer's Sheet on Appendix page B-39

The count in this register determines the baud rate of the SCI. The formula for calculating baud rate is:

$$\text{SCI baud rate} = \frac{\text{SCI module clock}}{16 \times \text{SBR}}$$

SBR = contents of the baud rate registers, a value of one to 8191

Note: The baud rate generator is disabled until the TE or the RE bits are set for the first time after reset. The baud rate generator is disabled when SBR = 0.

9.8.2 SCI Control Register (SCICR)

The SCI Control Register can be read/written at anytime.

Base + $1	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	LOOP	SWAI	RSRC	M	WAKE	POL	PE	PT	TEIE	TIIE	RFIE	REIE	TE	RE	RWU	SBK
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 9-18. SCI Control Register (SCICR)

See Programmer's Sheet on Appendix page B-40

9.8.2.1 Loop Select Bit (LOOP)—Bit 15

This bit enables Loop operation. The Loop operation disconnects the RXD pin from the SCI and the transmitter output goes into the receiver input. Both the transmitter and the receiver must be enabled to use the internal loop function as opposed to single-wire operation, requiring only one or the other to be enabled. Please see **Table 9-9.**

- 0 = Normal operation enabled
- 1 = Loop operation enabled

The receiver input is determined by the RSRC bit. The transmitter output is controlled by the TE bit.

If the TE bit is set and LOOP = 1, the transmitter output appears on the TXD pin. If the TE bit is clear and LOOP = 1, the TXD pin is high-impedance.

Table 9-9. Loop Functions

LOOP	RSRC	Function
0	X	Normal operation
1	0	Loop mode with internal TXD fed back to RXD
1	1	Single-wire mode with TXD output fed back to RXD

9.8.2.2 Stop in Wait Mode Bit (SWAI)—Bit 14

The SWAI bit disables the SCI in the Wait mode.

- 0 = SCI enabled in Wait mode
- 1 = SCI disabled in Wait mode

9.8.2.3 Receiver Source (RSRC)— Bit 13

When LOOP = 1, the RSRC bit determines the internal feedback path for the receiver.

- 0 = Receiver input internally connected to transmitter output
- 1 = Receiver input connected to TXD pin

9.8.2.4 Data Format Mode (M)—Bit 12

This bit determines whether data characters are eight or nine bits long.

- 0 = One Start bit, eight data bits, one Stop bit
- 1 = One Start bit, nine data bits, one Stop bit

9.8.2.5 Wake up Condition (WAKE)—Bit 11

This bit determines which condition wakes up the SCI: Logic 1 (address mark) in the MSB position of a received data character or an idle condition on the RXD pin.

- 0 = Idle line wake up
- 1 = Address mark wake up

9.8.2.6 Polarity (POL)—Bit 10

This bit determines whether to invert the data as it goes from the transmitter to the TXD pin and from the RXD pin to the receiver. All bits, Start, Data, and Stop, will be inverted as they leave the Transmit Shift Register and before they enter the Receive Shift Register.

- 0 = Doesn’t invert transmit and receive data bits (Normal mode)
- 1 = Invert transmit and receive data bits (Inverted mode)

Note: It is recommended the POL bit be toggled only when both TE and RE = 0.

9.8.2.7 Parity Enable (PE)—Bit 9

This bit enables the parity function. When enabled, the parity function replaces the MSB of the data character with a parity bit.

- 0 = Parity function disabled
- 1 = Parity function enabled

9.8.2.8 Parity Type (PT)—Bit 8

This bit determines whether the SCI generates and checks for even parity or odd parity of the data bits. With even parity, an *even* number of *ones* clears the parity bit and an *odd* number of *ones* sets the parity bit. With odd parity, an *odd* number of *ones* clears the parity bit and an *even* number of *ones* sets the parity bit.

- 0 = Even parity
- 1 = Odd parity

9.8.2.9 Transmitter Empty Interrupt Enable (TEIE)—Bit 7

This bit enables the Transmit Data Register Empty (TDRE) flag to generate interrupt requests.

- 0 = TDRE interrupt requests disabled
- 1 = TDRE interrupt requests enabled

9.8.2.10 Transmitter Idle Interrupt Enable (TIIE)—Bit 6

This bit enables the Transmitter Idle (TIDLE) flag to generate interrupt requests.

- 0 = TIDLE interrupt requests disabled
- 1 = TIDLE interrupt requests enabled

9.8.2.11 Receiver Full Interrupt Enable (RFIE)—Bit 5

This bit enables the Receive Data Register Full (RDRF) flag, or the Overrun (OR) flag to generate interrupt requests.

- 0 = RDRF and OR interrupt requests disabled
- 1 = RDRF and OR interrupt requests enabled

9.8.2.12 Receive Error Interrupt Enable (REIE)—Bit 4

This bit enables the Receive Error (RE) flags (NF, PF, FE, and OR) to generate interrupt requests.

- 0 = Error interrupt requests disabled
- 1 = Error interrupt requests enabled

9.8.2.13 Transmitter Enable (TE)—Bit 3

This bit enables the SCI transmitter and configures the TXD pin as the SCI transmitter output. The TE bit can be used to queue an idle preamble.

- 0 = Transmitter disabled
- 1 = Transmitter enabled

9.8.2.14 Receiver Enable (RE)—Bit 2

This bit enables the SCI Receiver.

- 0 = Receiver disabled
- 1 = Receiver enabled

9.8.2.15 Receiver Wake Up (RWU)—Bit 1

This bit enables the wake up function, inhibiting further receiver interrupt requests. Normally, hardware wakes the receiver by automatically clearing the RWU. Please refer to **Section 9.5.4.8** for a description of Receive Wake Up.

- 0 = Normal operation
- 1 = Standby state

9.8.2.16 Send Break (SBK)—Bit 0

Toggling SBK sends one break character (10 or 11 logic zeros). As long as SBK is set, the transmitter sends logic zeros.

- 0 = No break characters
- 1 = Transmit break characters

9.8.3 SCI Status Register (SCISR)

This register can be read at anytime; however, it cannot be modified by writing. Writes clear flags.

Base + $3	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	TDRE	TIDLE	RDRF	RIDLE	OR	NF	FE	PF	0	0	0	0	0	0	0	RAF
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 9-19. SCI Status Register (SCISR)

See Programmer's Sheet on Appendix page B-43

9.8.3.1 Transmit Data Register Empty Flag (TDRE)—Bit 15

This bit is set when the Transmit Shift Register receives a character from the SCI Data Register (SCIDR). Clear TDRE by reading SCISR with TDRE set and then writing to the SCI Data Register in normal mode or by writing the SCIDR with TDE set.

- 0 = No character transferred to transmit Shift Register
- 1 = Character transferred to transmit Shift Register; transmit data register empty

9.8.3.2 Transmitter Idle Flag (TIDLE)—Bit 14

This bit is set when the TDRE flag is set and no data, preamble, or break character is being transmitted. When TIDLE is set, the TXD pin becomes idle (Logic 1). Clear TIDLE by reading the SCI Status Register (SCISR) with TIDLE set and then writing to the SCI Data Register (SCIDR). TIDLE is not generated when a data character, a preamble, or a break is queued and ready to be sent.

- 0 = Transmission in progress
- 1 = No transmission in progress

9.8.3.3 Receive Data Register Full Flag (RDRF)—Bit 13

This bit is set when the data in the Receive Shift Register transfers to the SCI Data Register (SCIDR). Clear RDRF by reading the SCI Status Register (SCISR) with RDRF set and then reading the SCI Data Register in Normal mode or by reading the SCIDR with RDE set.

- 0 = Data not available in SCI Data register
- 1 = Received data available in SCI Data register

9.8.3.4 Receiver Idle Line Flag (RIDLE)—Bit 12

This bit is set when 10 consecutive Logic 1s (if M = 0) or 11 consecutive Logic 1s (if M = 1) appear on the receiver input. Once the RIDLE flag is cleared (the receiver detects a logic zero), a valid frame must again set the RDRF flag before an idle condition can set the RIDLE flag.

- 0 = Receiver input is either active now or has never become active since the RIDLE flag was last cleared
- 1 = Receiver input has become idle (after receiving a valid frame)

Note: When the Receiver Wake up (RWU) bit is set, an idle line condition *does not set the RIDLE flag.*

9.8.3.5 Overrun Flag (OR)—Bit 11

This bit is set when software fails to read the SCI Data Register (SCIDR) before the Receive Shift Register receives the next frame. The data in the Shift Register is lost, but the data already in the SCI Data Register is not affected. Clear OR by reading the SCI Status Register (SCISR) with OR set, then write the SCI Status Register with any value.

- 0 = No overrun
- 1 = Overrun

9.8.3.6 Noise Flag (NF)—Bit 10

This bit is set when the SCI detects noise on the receiver input. The NF bit is set during the same cycle as the RDRF flag but is not set in the case of an overrun. Clear NF by reading the SCI Status Register (SCISR) then write the SCI Status Register with any value.

- 0 = No noise
- 1 = Noise

9.8.3.7 Framing Error Flag (FE)—Bit 9

This bit is set when Logic 0 is accepted as the Stop bit. FE bit is set during the same cycle as the RDRF flag but it is not set in the case of an overrun. FE inhibits further data reception until it is cleared. Clear FE by reading the SCISR with FE set, then write the SCISR with any value.

- 0 = No framing error
- 1 = Framing error

9.8.3.8 Parity Error Flag (PF)—Bit 8

This bit is set when the parity enable bit, PE, is set and the parity of the received data does not match its parity bit. Clear PF by reading the SCISR then write the SCISR with any value.

- 0 = No parity error
- 1 = Parity error

9.8.3.9 Reserved—Bits 7–1

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

9.8.3.10 Receiver Active Flag (RAF)—Bit 0

This bit is set when the receiver detects a Logic 0 during the RT1 time period of the Start bit search. RAF is cleared when the receiver detects false Start bits (usually from noise or baud rate mismatch) or when the receiver detects a preamble.

- 0 = No reception in progress
- 1 = Reception in progress

9.8.4 SCI Data Register (SCIDR)

The SCI Data Register can be read and modified at any time. Reading accesses SCI Receive Data Register (SRDR). Writing to the register accesses SCI Transmit Data Register (STDR).

Base + $4	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	RECEIVE DATA								
Write								TRANSMIT DATA								
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 9-20. SCI Data Register (SCIDR)

See Programmer's Sheet on Appendix page B-46

9.8.4.1 Reserved—Bits 15–9

These bits are reserved or not implemented. They are read as, and written with 0.

9.8.4.2 Receive Data—Bits 8–0

Data received.

9.8.4.3 Transmit Data—Bits 8–0

Data to be transmitted.

9.9 Clocks

All timing is derived from the IPBus clock at half of the system clock for this module. Please see **Section 9.5.2** for a description of how the data rate is determined.

9.10 Resets

Reset characteristics are determined by the state of Control register bit settings. Therefore, the register descriptions comprising **Section 9.8** cover all reset functions.

9.11 Interrupts

Table 9-10. SCI Interrupt Sources

Interrupt Source	Flag	Local Enable
Transmitter	TDRE	TEIE
Transmitter	TIDLE	TIIE
Receiver	RDRF	RFIE
	OR	
Receiver	FE	REIE
	PE	
	NF	
	OR	

9.11.1 Transmitter Empty Interrupt

This interrupt is enabled by setting the TEIE bit of the SCICR. When this interrupt is enabled an interrupt is generated when data is transferred from the SCI Data Register to the Transmit Shift Register. The interrupt service routine should read the SCISR and verify the TDRE bit is set, and then write the next data to be transmitted to the SCIDR, will clear the TDRE bit.

9.11.2 Transmitter Idle Interrupt

This interrupt is enabled by setting the TIIE bit of the SCICR. This interrupt indicates the TDRE flag is set and the transmitter is no longer sending data, preamble, or break characters. The interrupt service routine should read the SCISR and verify the TIDLE bit is set and then initiate a preamble, break, or write a data character to the SCIDR. Any of these actions will clear the TIDLE bit since the transmitter will then be busy.

9.11.3 Receiver Full Interrupt

This interrupt is enabled by setting the RIE bit of the SCICR. This interrupt indicates Receive Data is available in the SCIDR. The interrupt service routine should read the SCISR and verify that the RDRF bit is set and then read the data from the SCISR, will clear the RDRF bit.

9.11.4 Receive Error Interrupt

This interrupt is enabled by setting the REIE bit of the SCICR. This interrupt indicates any of the listed errors was detected by the receiver

1. Noise Flag (NF) set
2. Parity error Flag (PF) set
3. Framing Error (FE) flag set
4. OverRun (OR) flag set

The interrupt service routine should read the SCISR to determine which of the error flags was set. The error flag is set by writing (anything) to the SCISR. Then the appropriate action should be taken by the software to handle the error condition.

9.11.5 Receiver Idle Interrupt

When this interrupt occurs the appropriate response of the interrupt service routine would be to disable the RIIE until the next message receive sequence occurs.

Chapter 10
Serial Peripheral Interface (SPI)

10.1 Introduction

This chapter describes the Serial Peripheral Interface (SPI) module. The module allows full-duplex, synchronous, serial communication between the controller and peripheral devices, including other controllers. Software can poll SPI status flags or SPI operation can be interrupt driven. This block contains four 16-bit memory mapped registers for control parameters, status, and data transfer.

10.2 Features

Features of the SPI module include:

- Full-duplex operation
- Master and slave modes
- Double-buffered operation with separate transmit and receive registers
- Programmable length transmissions (2 to 16 bits)
- Programmable transmit and receive shift order (MSB first or last bit transmitted)
- Eight master mode frequencies (maximum = bus frequency ÷ 2)
- Maximum slave mode frequency = bus frequency
- Clock ground for reduced radio frequency (RF) interference
- Serial clock with programmable polarity and phase
- Two separately enabled interrupts
  - SPRF (SPI Receiver Full)
  - SPTE (SPI Transmitter Empty)
- Mode fault error flag interrupt capability
- Wired OR mode functionality to enabling connection to multiple SPIs

10.3 SPI Block Diagram

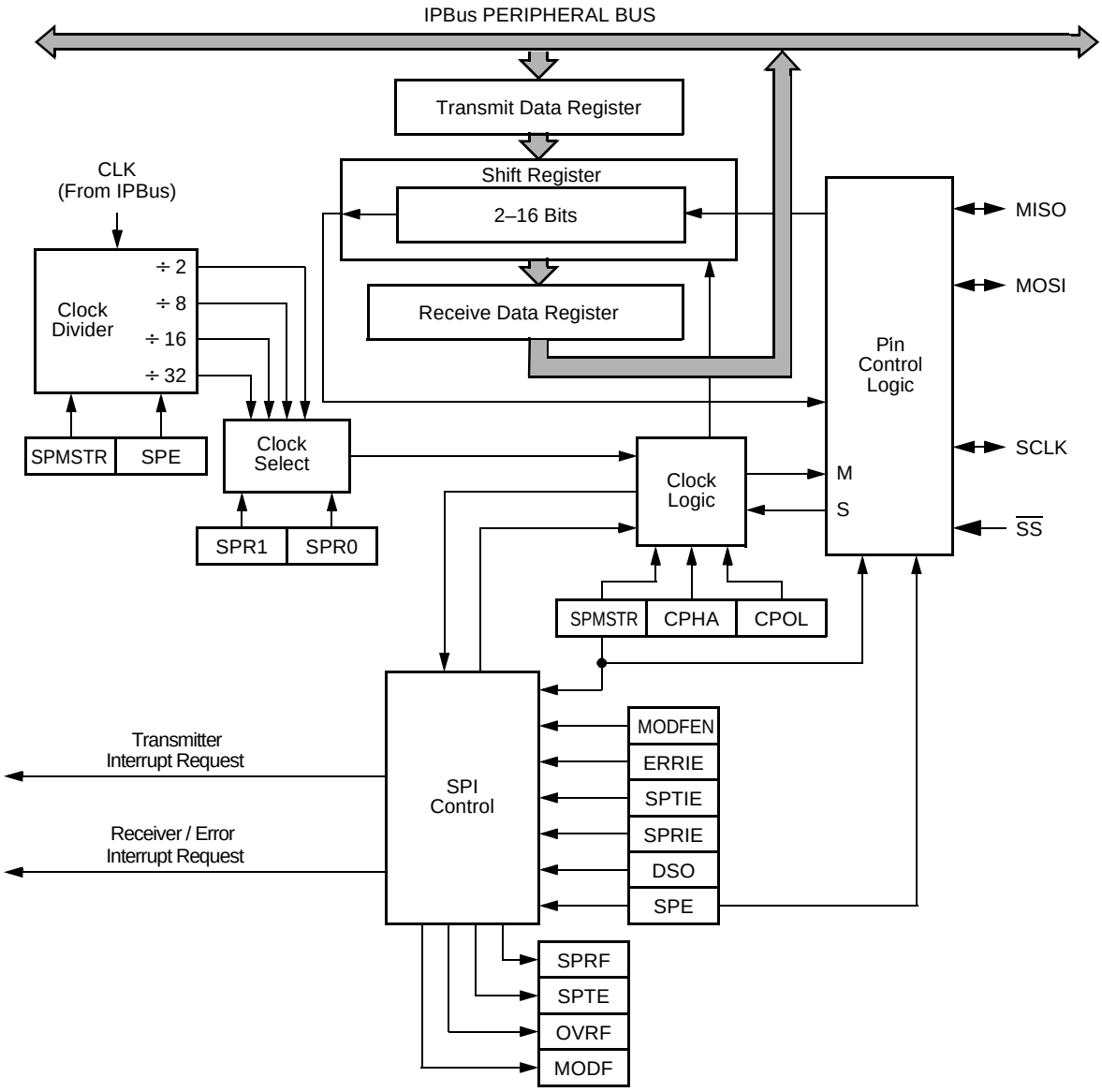


Figure 10-1. SPI Block Diagram

10.4 Signal Descriptions

10.4.1 Master In/Slave Out (MISO)

MISO is one of the two SPI module pins dedicated to transmit serial data. In full duplex operation, the MISO pin of the master SPI module is connected to the MISO pin of the slave SPI module. The master SPI simultaneously receives data on its MISO pin and transmits data from its MOSI pin.

Slave output data on the MISO pin is enabled only when the SPI is configured as a slave. The SPI is configured as a slave when the SPMSTR bit, illustrated in **Figure 10-13**, is Logic 0 and its $\overline{SS}$ pin is at Logic 0. To support a multiple slave system, a Logic 0 on the $\overline{SS}$ pin puts the MISO pin in a High-Z state.

10.4.2 Master Out/Slave In (MOSI)

MOSI is the other SPI module pin dedicated to transmit serial data. In full duplex operation, the MOSI pin of the master SPI module is connected to the MOSI pin of the slave SPI module. The master SPI simultaneously transmits data from its MOSI pin and receives data on its MISO pin.

10.4.3 Serial Clock (SCLK)

The serial clock synchronizes data transmission between master and slave devices. In a master controller, the SCLK pin is the clock output. In a slave controller, the SCLK pin is the clock input. In full duplex operation, the master and slave controller exchange data in the same number of clock cycles as the number of bits of transmitted data.

10.4.4 Slave Select ($\overline{SS}$)

The $\overline{SS}$ pin has various functions depending on the current state of the SPI. For an SPI configured as a slave, the $\overline{SS}$ is used to select a slave. When the Clock Phase (CPHA) bit in the SPSCR is cleared, the $\overline{SS}$ is used to define the start of a transmission, so it must be toggled high and low between each full length data transmitted for the CPHA = 0 format. However, it can remain low between transmissions for the CPHA = 1 format as illustrated in **Figure 10-2.**

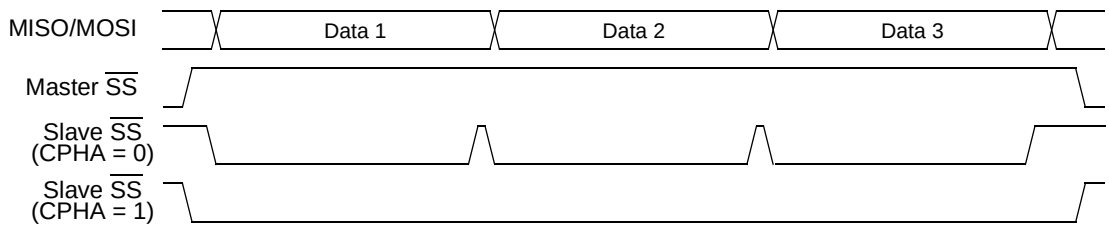


Figure 10-2. CPHA/$\overline{SS}$ Timing

When an SPI is configured as a slave, the $\overline{SS}$ pin is always configured as an input. The MODFEN bit can prevent the state of the $\overline{SS}$ from creating a MODF error.

Note: A Logic 1 voltage on the $\overline{SS}$ pin of a slave SPI puts the MISO pin in a high impedance state. The slave SPI ignores all incoming SCLK clocks, even if it was already in the middle of a transmission. A mode fault occurs if the $\overline{SS}$ pin changes state during a transmission.

When an SPI is configured as a master, the $\overline{SS}$ input can be used in conjunction with the MODF flag to prevent multiple masters from driving MOSI and SCLK. For the state of the $\overline{SS}$ pin to set the MODF flag, the MODFEN bit in the SCLK register must be set.

Table 10-1. SPI I/O Configuration

SPE	SPMSTR	MODFEN	SPI Configuration	State of $\overline{SS}$ Logic
0	X	X	Not Enabled	$\overline{SS}$ ignored by SPI
1	0	X	Slave	Input-only to SPI
1	1	0	Master without MODF	$\overline{SS}$ ignored by SPI
1	1	1	Master with MODF	Input-only to SPI

X = Don't care

10.5 External I/O Signals

There are four external SPI pins. Each is summarized in **Table 10-2.**

Table 10-2. External I/O Signals

Signal Name	Description	Direction
MOSI	Master-Out Slave-In Pad Pin	Bi-Directional
MISO	Master-In Slave-Out Pad Pin	Bi-Directional
SCLK	Slack Clock Pad Pin	Bi-Directional
$\overline{SS}$	Slave Select Pad Pin (Active Low)	Input

10.6 Operating Modes

The SPI has two operating modes:

1. Master
2. Slave

An operating mode is selected by the SPMSTR bit in the SPSCR as follows:

- SPMSTR = 0 Slave mode
- SPMSTR = 1 Master mode

Note: The SPMSTR bit should be configured before enabling the SPI, setting the SPE bit in the SPSCR. The master SPI should be enabled before enabling any slave SPI. All slave SPIs should be disabled before disabling the master SPI.

10.6.1 Master Mode

The SPI operates in Master mode when the SPI master bit, SPMSTR, is set.

Note: Configure the SPI module as master or slave before enabling the SPI. Enable the master SPI before enabling the slave SPI. Disable the slave SPI before disabling the master SPI.

Only a Master SPI module can initiate transmissions. With the SPI enabled, software begins the transmission from the master SPI module by writing to the SPI Data Transmit Register (SPDTR). If the Shift Register is empty, the data immediately transfers to the Shift Register, setting the SPI Transmitter Empty (SPTE) bit. The data begins shifting out on the MOSI pin under the control of the SPI Serial Clock (SCLK).

The SPR1 and SPR0 bits in the SPSCR control the baud rate generator and determine the speed of the Shift Register. The baud rate generator of the master also controls the Shift Register of the slave peripheral via the SCLK pin.

As the data shifts out on the MOSI pin of the master, external data shifts in from the slave on the master's MISO pin. The transmission ends when the SPI Receiver Full (SPRF) bit in the SPSCR becomes set. At the same time the SPRF becomes set, the data from the slave transfers to the SPI Data Receive Register (SPDRR). In a normal operation, SPRF signals the end of a transmission. Software clears the SPRF by reading the SPSCR register with SPRF set and then reading the SPI Data Receive register, SPDRR. Writing to the SPI Data Transmit register, SPDTR, clears the SPTE bit.

Figure 10-3 is an example configuration for a Full-Duplex Master-Slave Configuration. Having the $\overline{SS}$ bit of the Master controller held high is only necessary if MODFEN = 1. Tying the Slave controller $\overline{SS}$ bit to ground should only be executed if CPHA = 1.

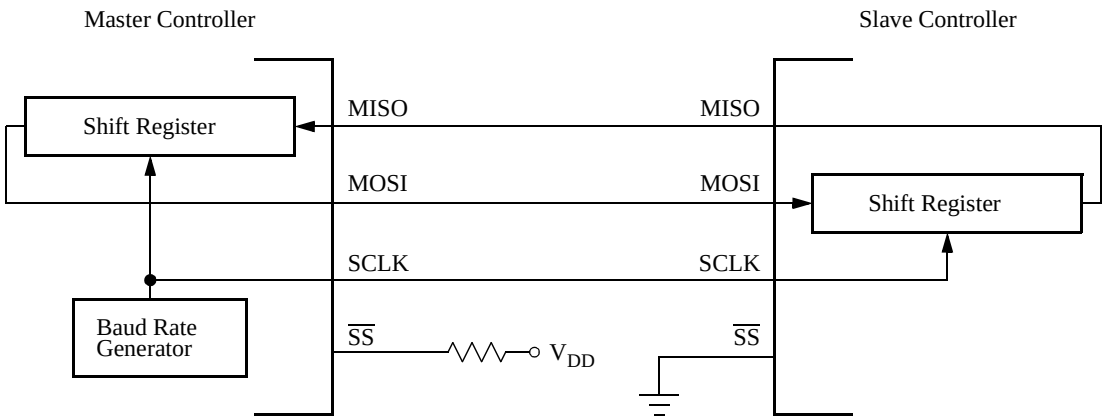


Figure 10-3. Full-Duplex Master/Slave Connections

10.6.2 Slave Mode

The SPI operates in the Slave mode when the SPMSTR bit is cleared. While in the Slave mode, the SCLK pin acts as the input for the serial clock from the master controller. Before a data transmission occurs, the $\overline{SS}$ pin of the slave SPI must be at Logic 0. $\overline{SS}$ must remain low until the transmission is complete or a Mode Fault error occurs.

Note: The SPI must be enabled (SPE = 1) for slave transmissions to be received.

Note: Data in the transmitter Shift Register will be unaffected by SCLK transitions in the event the SPI is operating as a slave but is deselected.

In a slave SPI module, data enters the Shift Register under the control of the serial clock, SCLK, from the master SPI module. After a full length data transmission enters the Shift Register of a slave SPI, it transfers to the SPDRR and the SPRF bit in the SPSCR is set. If the Receive Interrupt Enable (SPRIE) bit in the SPSCR has been set, a receive interrupt is also generated. To prevent an overflow condition, slave software must read the SPDRR before another full length data transmission enters the Shift Register.

The maximum frequency of the SCLK for an SPI configured as a slave is the bus clock speed. The bus clock speed is twice as fast as the fastest master SCLK potential generation. Frequency of the SCLK for an SPI configured as a slave does not have to correspond to any particular SPI baud rate. The baud rate only controls the speed of the SCLK generated by an SPI configured as a master. Therefore, the frequency of the SCLK for an SPI configured as a slave can be any frequency less than or equal to the bus speed.

When the master SPI starts a transmission, the data in the slave Shift Register begins shifting out on the MISO pin. The slave can load its Shift Register with new data for the next transmission by writing to its Transmit Data Register. The slave must write to its Transmit Data Register at least one bus cycle before the master starts the next transmission. Otherwise, the data already in the slave Shift Register shifts out on the MISO pin. Data written to the slave Shift Register during a transmission remains in a buffer until the end of the transmission.

When the CPHA bit is set, the first edge of SCLK starts a transmission. When CPHA is cleared, the falling edge of $\overline{SS}$ starts a transmission.

Note: SCLK must be in the proper idle state before the slave is enabled to prevent SCLK from appearing as a clock edge.

10.6.3 Wired OR Mode

Wired-OR functionality is provided to permit the connection of multiple SPIs. **Figure 10-4** illustrates a single master controlling multiple slave SPIs. When the WOM bit is set, the outputs switch from conventional complementary CMOS output to open drain outputs. This lets the internal pull-up resistor bring the line high, and whichever SPI drives the line pulls it low as needed.

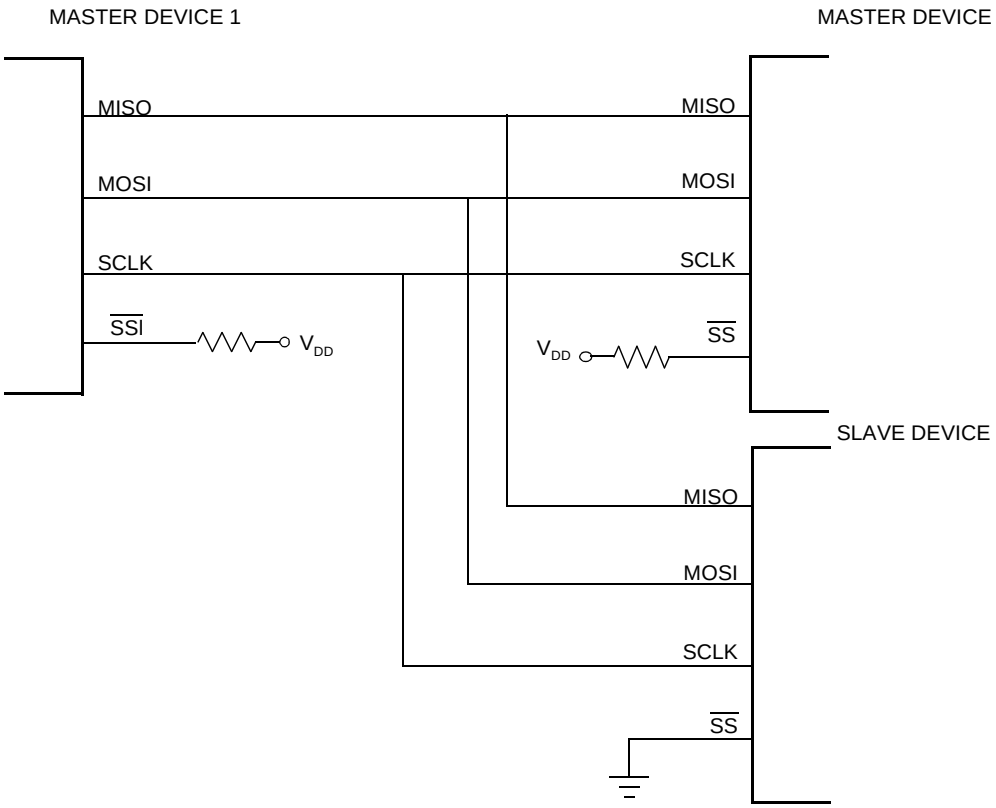


Figure 10-4. Sharing of a Slave by Multiple Masters

10.7 Transmission Formats

During an SPI transmission, data is simultaneously transmitted, or shifted out serially, and received, that is shifted in serially. A serial clock synchronizes shifting and sampling on the two serial data lines. A slave select line allows selection of an individual slave SPI device; slave devices not selected do not interfere with SPI bus activities. On a master SPI device, the Slave Select line can optionally be used to indicate multiple-master bus contention.

10.7.1 Data Transmission Length

The SPI can support data lengths from one to 16 bits. This can be configured in the Data Size Register (SPDSR). When the data length is less than 16 bits, the Receive Data register will pad the upper bits with zeros. It is the responsibility of the software to remove these upper bits since 16 bits will be read when reading the Receive Data Register (SPDRR).

Note: Data can be lost if the data length is not the same for both master and slave devices.

10.7.2 Data Shift Ordering

The SPI can be configured to transmit or receive the MSB of the desired data first or last. This is controlled by the Data Shift Order (DSO) bit in the SPSCR. Regardless which bit is transmitted or received first, the data shall always be written to the SPI Data Transmit Register (SPDTR) and read from the Receive Data Register (SPDRR) with the LSB in bit 0 and the MSB in the correct position, depending on the data transmission size.

10.7.3 Clock Phase and Polarity Controls

Software can select any of four combinations of Serial Clock (SCLK) phase and polarity using two bits in the SPI Status and Control Register (SPSCR). The Clock Polarity is specified by the (CPOL) control bit. In turn, it selects an active high or low clock and has no significant effect on the transmission format.

The Clock Phase (CPHA) control bit selects one of two fundamentally different transmission formats. The clock phase and polarity should be identical for the master SPI device and the communicating slave device. In some cases, the phase and polarity are changed between transmissions to allow a master device to communicate with peripheral slaves having different requirements.

Note: Before writing to the CPOL bit or the CPHA bit, disable the SPI by clearing the SPI Enable (SPE) bit.

10.7.4 Transmission Format When CPHA = 0

Figure 10-5 exhibits an SPI transmission with CPHA as Logic 0. The figure should not be used as a replacement for data sheet parametric information. Two waveforms for the SCLK:

1. CPOL = 0
2. CPOL = 1

The diagram may be interpreted as a master or slave timing diagram since the Serial Clock (SCLK), Master In/Slave Out (MISO), and Master Out/Slave In (MOSI) pins are directly

connected between the master and the slave. The MISO signal is the output from the slave, and the MOSI signal is the output from the master.

The $\overline{SS}$ line is the slave select input to the slave. The slave SPI drives its MISO output only when its slave select input ($\overline{SS}$) is at Logic 0, because only the selected slave drives to the master. The $\overline{SS}$ pin of the master is not shown, but it is assumed to be inactive. The $\overline{SS}$ pin of the master must be high or a mode fault error will occur. When CPHA = 0, the first SCLK edge is the MSB capture strobe. Therefore, the slave must begin driving its data before the first SCLK edge and a falling edge on the $\overline{SS}$ pin is used to start the slave data transmission. The slave's $\overline{SS}$ pin must be toggled back to high and then low again between each full length data transmitted as depicted in **Figure 10-6.**

Note: **Figure 10-5** assumes 16-bit data lengths and the MSB shifted out first.

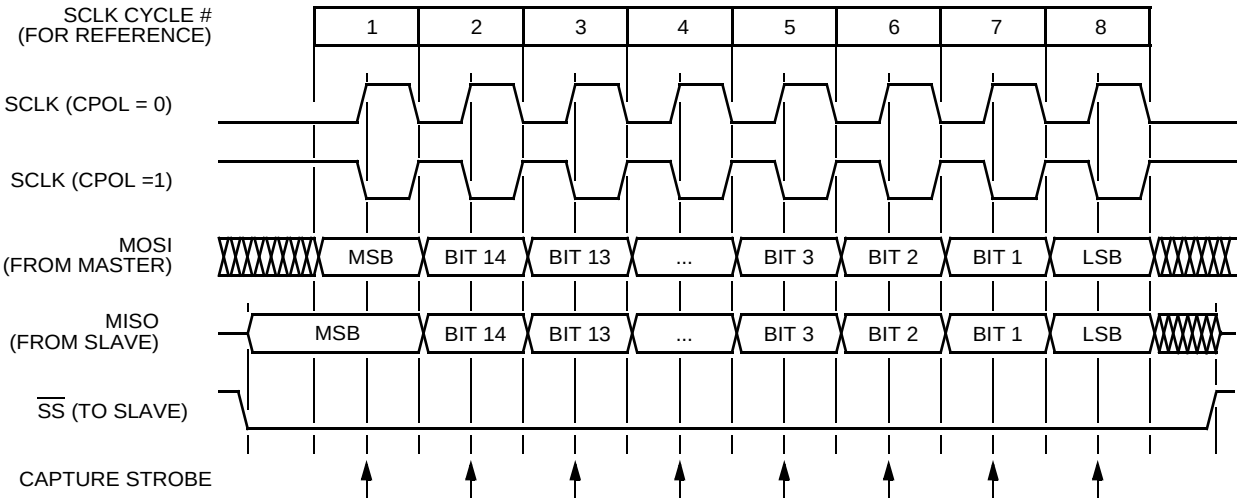


Figure 10-5. Transmission Format (CPHA = 0)

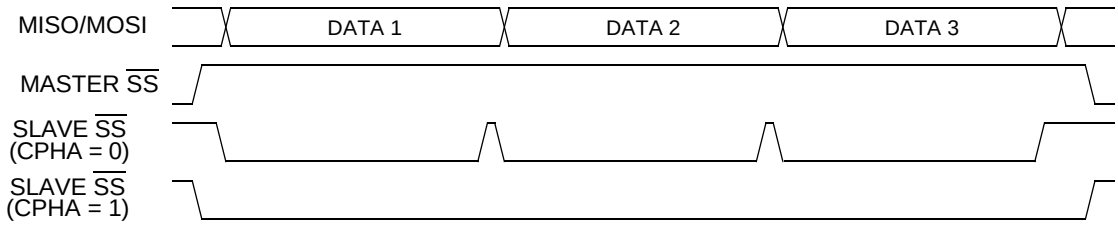


Figure 10-6. CPHA/$\overline{SS}$ Timing

When CPHA = 0 for a slave, the falling edge of $\overline{SS}$ indicates the beginning of the transmission. This causes the SPI to leave its idle state and begin driving the MISO pin with the first bit of its data. Once the transmission begins, no new data is allowed into the Shift Register from the Transmit Data Register. Therefore, the SPI Data Register of the slave must be loaded with

transmit data before the falling edge of $\overline{SS}$. Any data written after the falling edge is stored in the Transmit Data Register and transferred to the Shift Register after the current transmission.

When CPHA = 0 for a master, normal operation would begin by the master initializing the $\overline{SS}$ pin of the slave high. A transfer would then begin by the master setting the $\overline{SS}$ pin of the slave low and then writing the SPDTR register. After completion of a data transfer, the $\overline{SS}$ pin would be put back into the high state by the master device.

10.7.5 Transmission Format When CPHA = 1

A SPI transmission is shown in **Figure 10-7** where CPHA is Logic 1. The figure should not be used as a replacement for data sheet parametric information. Two waveforms are shown for SCLK: 1 for CPOL = 0 and another for CPOL = 1. The diagram may be interpreted as a master or slave timing diagram since the serial clock (SCLK), Master In/Slave Out (MISO), and Master Out/Slave In (MOSI) pins are directly connected between the master and the slave. The MISO signal is the output from the slave, and the MOSI signal is the output from the master. The $\overline{SS}$ line is the slave select input to the slave. The slave SPI drives its MISO output only when its slave select input ($\overline{SS}$) is at Logic 0, so only the selected slave drives to the master. The $\overline{SS}$ pin of the master is not shown but is assumed to be inactive. The $\overline{SS}$ pin of the master must be high or a mode fault error will occur. When CPHA = 1, the master begins driving its MOSI pin on the first SCLK edge. Therefore, the slave uses the first SCLK edge as a start transmission signal. The $\overline{SS}$ pin can remain low between transmissions. This format may be preferable in systems having only one master and slave driving the MISO data line.

Note: **Figure 10-7** assumes 16-bit data lengths and the MSB shifted out first.

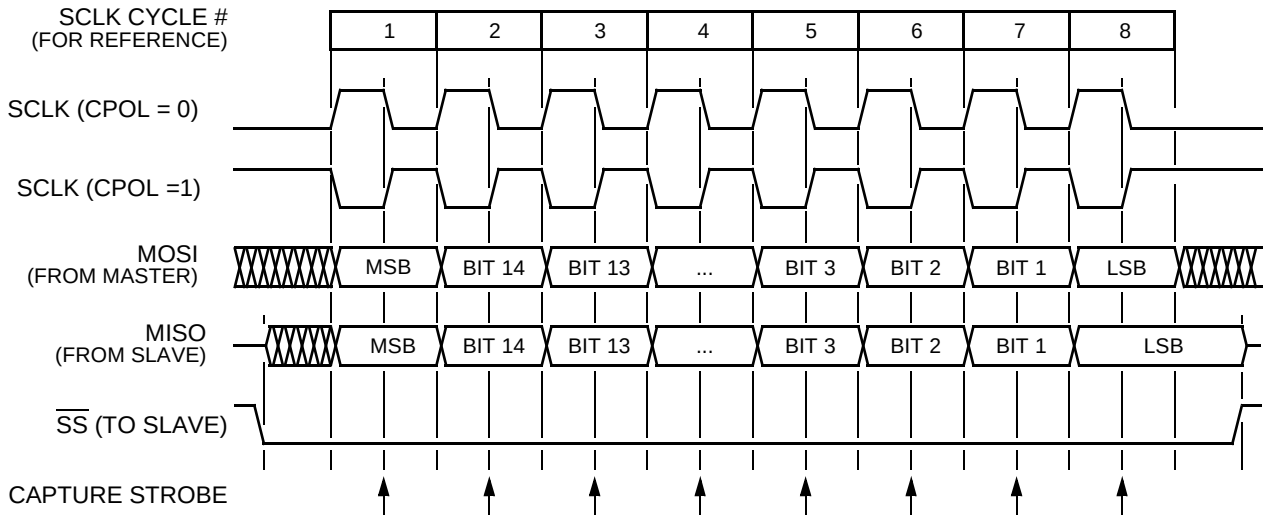


Figure 10-7. Transmission Format (CPHA = 1)

When CPHA = 1 for a slave, the first edge of the SCLK indicates the beginning of the transmission. This causes the SPI to leave its idle state and begin driving the MISO pin with the first bit of its data. Once the transmission begins, no new data is allowed into the Shift Register from the Transmit Data Register. Therefore, the SPI Data Register of the slave must be loaded with transmit data before the first edge of SCLK. Any data written after the first edge is stored in the Transmit Data Register and transferred to the Shift Register after the current transmission.

10.7.6 Transmission Initiation Latency

When the SPI is configured as a master (SPMSTR = 1), writing to the SPDTR starts a transmission. CPHA has no effect on the delay to the start of the transmission, but it does affect the initial state of the SCLK signal. When CPHA = 0, the SCLK signal remains inactive for the first half of the first SCLK cycle. When CPHA = 1, the first SCLK cycle begins with an edge on the SCLK line from its inactive to its active level. The SPI clock rate, selected by SPR1:SPR0, affects the delay from the write to SPDTR and the start of the SPI transmission. The internal SPI clock in the master is a free-running derivative of the internal clock. To conserve power, it is enabled only when both the SPE and SPMSTR bits are set. Since the SPI clock is free-running, it is uncertain where the write to the SPDTR occurs relative to the slower SCLK. This uncertainty causes the variation in the initiation delay, demonstrated in **Figure 10-8.** This delay is no longer than a single SPI bit time. That is, the maximum delay is two bus cycles for DIV2, four bus cycles for DIV4, eight bus cycles for DIV8, and so on up to a maximum of 128 cycles for DIV128.

Note: **Figure 10-8** assumes 16-bit data lengths and the MSB shifted out first.

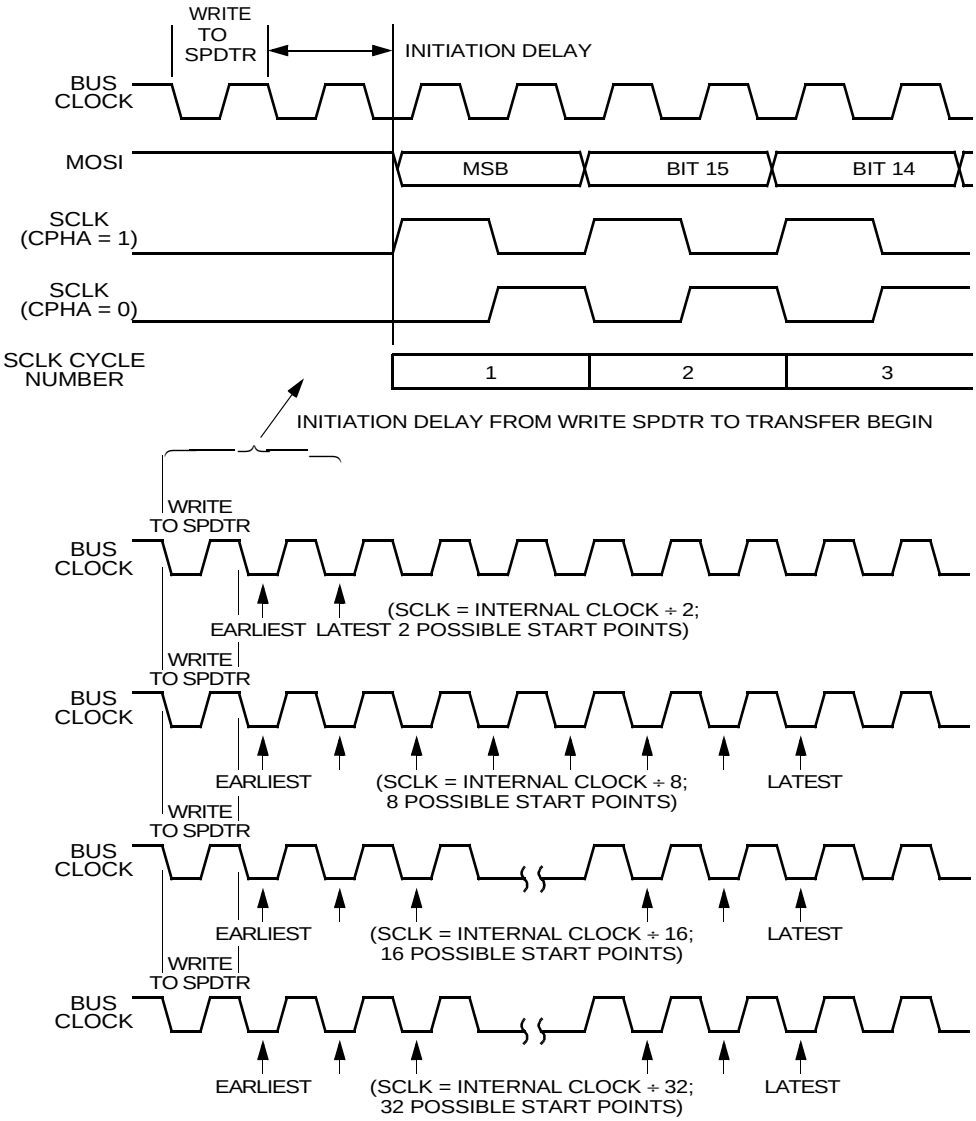
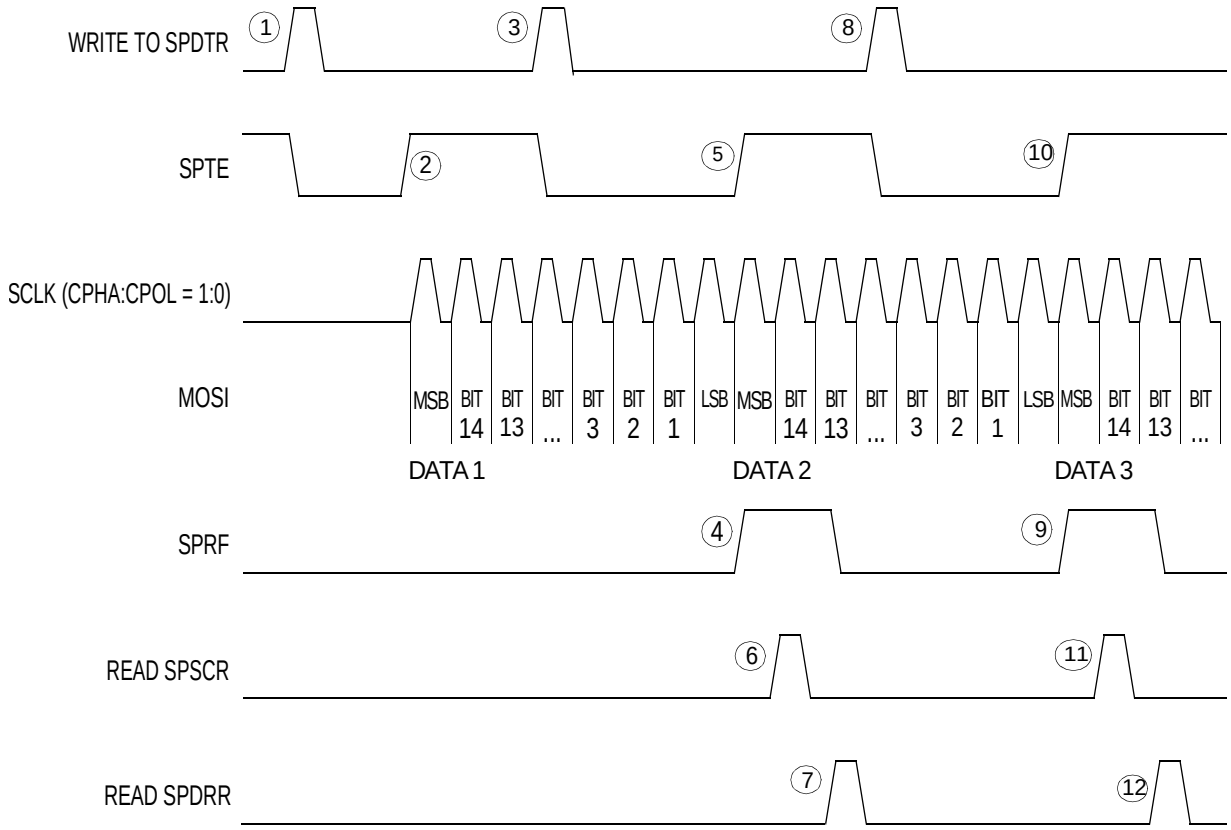


Figure 10-8. Transmission Start Delay (Master)

10.8 Transmission Data

The double-buffered Transmit Data Register (TDR) allows data to be queued and transmitted. For an SPI configured as a master, the queued data is transmitted immediately after the previous transmission has completed. The SPI Transmitter Empty (SPTE) flag indicates when the transmit data buffer is ready to accept new data. Write to the TDR only when the SPTE bit is high. **Figure 10-9** illustrates the timing associated with doing back-to-back transmissions with the SPI (SCLK has CPHA: CPOL = 1:0).

Note: **Figure 10-9** assumes 16-bit data lengths and the MSB shifted out first.


WRITE TO SPDTR
SPTE
SCLK (CPHA:CPOL = 1:0)
MOSI
SPRF
READ SPSCR
READ SPDRR
MSB BIT 14 BIT 13 BIT ... BIT 3 BIT 2 BIT 1 LSB
MSB BIT 14 BIT 13 BIT ... BIT 3 BIT 2 BIT 1 LSB
MSB BIT 14 BIT 13 BIT ...
DATA 1
DATA 2
DATA 3

1. CONTROLLER WRITES DATA 1 TO SPDTR, CLEARING THE SPTE BIT.
2. DATA 1TRANSFERS FROM TRANSMIT DATA REGISTER TO SHIFT REGISTER, SETTING SPTE BIT.
3. CONTROLLER WRITES DATA 2 TO SPDTR, QUEUEING DATA 2 AND CLEARING SPTE BIT.
4. FIRST INCOMING WORD TRANSFERS FROM THE SHIFT REGISTER TO THE RECEIVE DATA REGISTER, SETTING THE SPRF BIT.
5. DATA 2 TRANSFERS FROM THE TRANSMIT DATA REGISTER TO SHIFT REGISTER, SETTING THE SPTIR BIT.
6. CONTROLLER READS SPSCR WITH THE SPRF BIT SET.
7. CONTROLLER READS SPDRR, CLEARING SPRF BIT.
8. CONTROLLER WRITES DATA 3 TO SPDTR, QUEUEING DATA 3 AND CLEARING THE SPTE BIT.
9. SECOND INCOMING DATA TRANSFERS FROM SHIFT REGISTER TO RECEIVE DATA REGISTER SETTING THE SPRF BIT.
10. DATA 3 TRANSFERSF ROM THE TRANSMIT DATA REGISTER TO THE SHIFT REGISTER, SETTING THE SPTE BIT.
11. CONTROLLER READS SPSCR WITH THE SPRF BIT.
12. CONTROLLER READS SPDRR, CLEARING THE SPRF BIT.

Figure 10-9. SPRF/SPTE Interrupt Timing

The transmit data buffer permits back-to-back transmissions without the slave precisely timing its writes between transmissions as is necessary in a system with a single data buffer. Also, if no new data is written to the data buffer, the last value contained in the Shift Register is the next data to be transmitted.

An idle master or idle slave without loaded data in its transmit buffer, sets the SPTE again no more than two bus cycles after the transmit buffer empties into the Shift Register. This allows a queue to send up to a 32-bit value. For an already active slave, the load of the Shift Register cannot occur until the transmission is completed. This implies a back-to-back write to the Transmit Data Register is not possible. The SPTE indicates when the next write can occur.

10.9 Error Conditions

The following flags signal SPI error conditions:

- Overflow (OVRF) — Failing to read the SPI Data Register before the next full length data enters the Shift Register sets the OVRF bit. The new data will not transfer to the Receive Data Register, and the unread data can still be read. OVRF is in the SPI Status and Control Register.
- Mode fault error (MODF) — The MODF bit indicates the voltage on the Slave Select pin ($\overline{SS}$) is inconsistent with the mode of the SPI. MODF is in the SPI Status and Control Register.

10.9.1 Overflow Error

The Overflow Flag (OVRF) becomes set if the Receive Data Register still has unread data from a previous transmission and when bit one's capture strobe of the next transmission occurs. Bit one capture strobe occurs in the middle of SCLK when the data length equals, transmission data length (-) one. If an overflow occurs, all data received after the overflow, and before the OVRF bit is cleared, does not transfer to the Receive Data Register. It does not set the SPI Receiver Full (SPRF) bit. The unread data transferred to the Receive Data Register before the overflow occurred can still be read. Therefore, an overflow error always indicates the loss of data. Clear the overflow flag by reading the SPI Status and Control Register, then read the SPI Data Register.

OVRF generates a receiver/error interrupt request if the error interrupt enable bit (ERRIE) is also set. It is not possible to enable MODF or OVRF individually to generate a receiver/error interrupt request. However, leaving MODFEN low prevents MODF from being set.

If the SPRF interrupt is enabled and the OVRF interrupt is not, watch for an overflow condition. **Figure 10-10** explains how it is possible to miss an overflow. The first element of the same figure illustrates how it is possible to read the SPSCR and SPDRR to clear the SPRF without problems. However, as illustrated by the second transmission example, the OVRF bit can be set between the time SPSCR and SPDRR are read.

In this case, an overflow can easily be missed. Since no more SPRF interrupts can be generated until this OVRF is serviced, it is not obvious data is being lost as more transmissions are completed. To prevent this loss, either enable the OVRF interrupt or take another read of the SPSCR following the read of the SPDRR. This ensures the OVRF was not set before the SPRF was cleared. Future transmissions can set the SPRF bit.

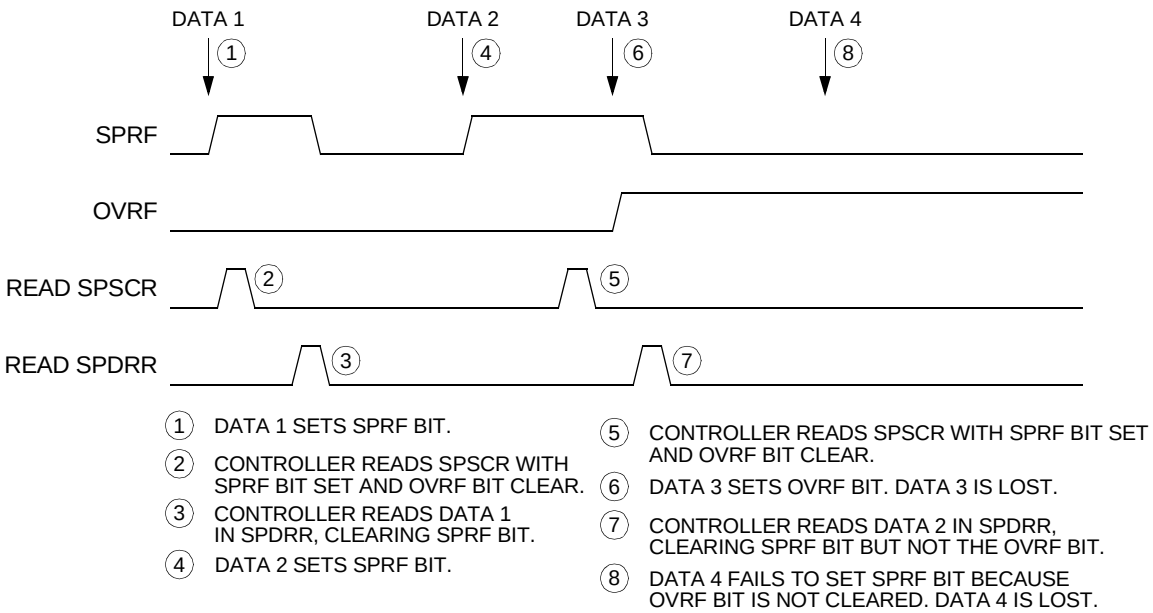

DATA 1
DATA 2
DATA 3
DATA 4
1
4
6
8
SPRF
OVRF
READ SPSCR
READ SPDRR
2
5
3
7
1 DATA 1 SETS SPRF BIT.
2 CONTROLLER READS SPSCR WITH SPRF BIT SET AND OVRF BIT CLEAR.
3 CONTROLLER READS DATA 1 IN SPDRR, CLEARING SPRF BIT.
4 DATA 2 SETS SPRF BIT.
5 CONTROLLER READS SPSCR WITH SPRF BIT SET AND OVRF BIT CLEAR.
6 DATA 3 SETS OVRF BIT. DATA 3 IS LOST.
7 CONTROLLER READS DATA 2 IN SPDRR, CLEARING SPRF BIT BUT NOT THE OVRF BIT.
8 DATA 4 FAILS TO SET SPRF BIT BECAUSE OVRF BIT IS NOT CLEARED. DATA 4 IS LOST.

Figure 10-10. Missed Read of Overflow Condition

Figure 10-11 illustrates the described process. Generally, to avoid a second SPSCR read, enable the OVRF to the core by setting the ERRIE bit.

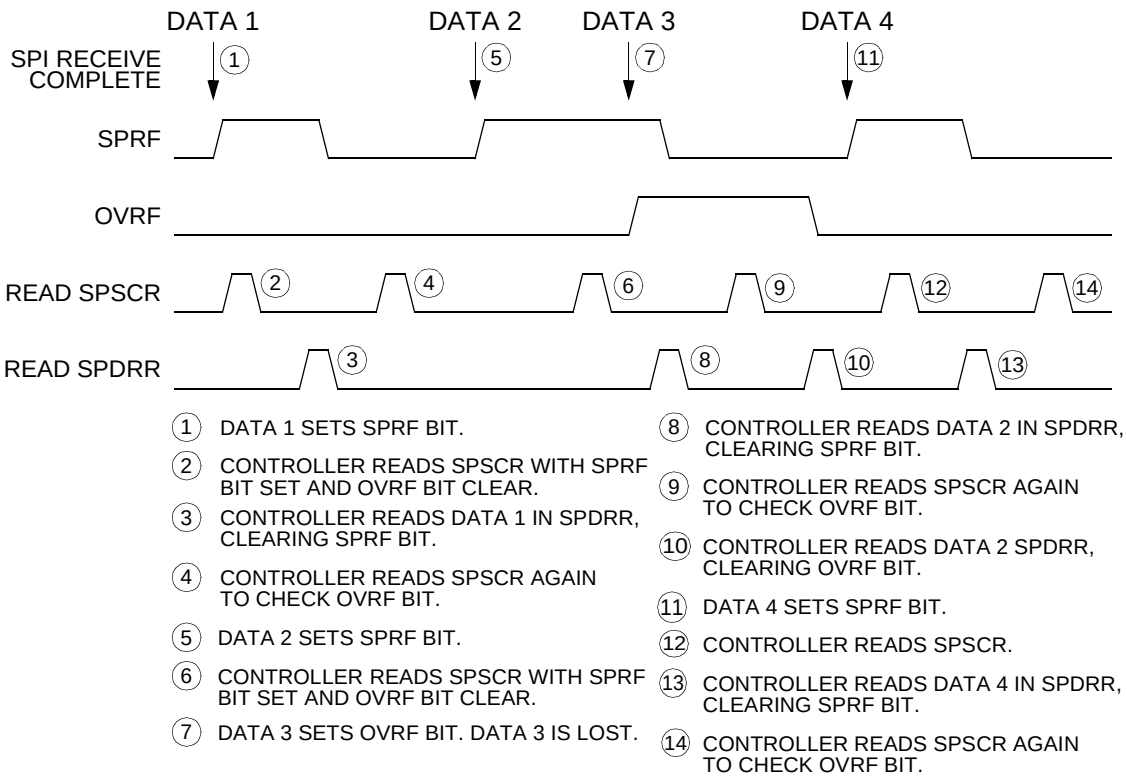

DATA 1
DATA 2
DATA 3
DATA 4
SPI RECEIVE COMPLETE
SPRF
OVRF
READ SPSCR
READ SPDRR
1 DATA 1 SETS SPRF BIT.
2 CONTROLLER READS SPSCR WITH SPRF BIT SET AND OVRF BIT CLEAR.
3 CONTROLLER READS DATA 1 IN SPDRR, CLEARING SPRF BIT.
4 CONTROLLER READS SPSCR AGAIN TO CHECK OVRF BIT.
5 DATA 2 SETS SPRF BIT.
6 CONTROLLER READS SPSCR WITH SPRF BIT SET AND OVRF BIT CLEAR.
7 DATA 3 SETS OVRF BIT. DATA 3 IS LOST.
8 CONTROLLER READS DATA 2 IN SPDRR, CLEARING SPRF BIT.
9 CONTROLLER READS SPSCR AGAIN TO CHECK OVRF BIT.
10 CONTROLLER READS DATA 2 SPDRR, CLEARING OVRF BIT.
11 DATA 4 SETS SPRF BIT.
12 CONTROLLER READS SPSCR.
13 CONTROLLER READS DATA 4 IN SPDRR, CLEARING SPRF BIT.
14 CONTROLLER READS SPSCR AGAIN TO CHECK OVRF BIT.

Figure 10-11. Clearing SPRF When OVRF Interrupt Is Not Enabled

10.9.2 Mode Fault Error

Setting the SPMSTR bit selects the Master mode, configuring the SCLK and MOSI pins as outputs and the MISO pin as an input. Clearing SPMSTR selects the Slave mode, configuring the SCLK and MOSI pins as inputs and the MISO pin as an output. The Mode Fault (MODF) bit becomes set any time the state of the slave select pin ($\overline{SS}$) is inconsistent with the mode selected by SPMSTR. To prevent SPI pin contention and damage to the controller, a mode fault error occurs if:

- The $\overline{SS}$ pin of a slave SPI goes high during a transmission.
- The $\overline{SS}$ pin of a master SPI goes low at any time.

To set the MODF flag, the Mode Fault Error Enable (MODFEN) bit must be set. Clearing the MODFEN bit does not clear the MODF flag but it does prevent the MODF from being set again after the MODF is cleared.

MODF generates a receiver/error interrupt request if the Error Interrupt Enable (ERRIE) bit is also set. It is not possible to enable MODF or OVRF individually to generate a receiver/error interrupt request. However, leaving MODFEN low prevents MODF from being set.

In a master SPI with the Mode Fault Enable (MODFEN) bit set, the Mode Fault (MODF) flag is set if $\overline{SS}$ goes to Logic 0. A mode fault in a Master SPI causes the following events to occur:

- If ERRIE = 1, the SPI generates an SPI receiver/error interrupt request.
  - The SPE bit is cleared
  - The SPTE bit is set
  - The SPI state counter is cleared

When configured as a slave (SPMSTR = 0), the MODF flag is set if the $\overline{SS}$ goes high during a transmission. When CPHA = 0, a transmission begins when $\overline{SS}$ goes low and ends once the incoming SCLK goes back to its idle level, following the shift of the last data bit. When CPHA = 1, the transmission begins when the SCLK leaves its idle level and $\overline{SS}$ is already low. The transmission continues until the SCLK returns to its idle level following the shift of the last data bit.

Note: Setting the MODF flag does not clear the SPMSTR bit. The SPMSTR bit has no function when SPE = 0. Reading SPMSTR when MODF = 1 shows the difference between a MODF occurring when the SPI is a master and when it is a slave.

When CPHA = 0, a MODF occurs if a slave is selected ($\overline{SS}$ is at Logic 0) and later unselected ($\overline{SS}$ is at Logic 1) even if no SCLK is sent to that slave. This happens because $\overline{SS}$ at Logic 0 indicates the start of the transmission (MISO driven out with the value of MSB) for CPHA = 0. When CPHA = 1, a slave can be selected and then later unselected with no transmission occurring. Therefore, MODF does not occur since a transmission was never begun.

In a slave SPI (MSTR = 0), the MODF bit generates an SPI Receiver/Error Interrupt request if the ERRIE bit is set. The MODF bit does not clear the SPE bit or reset the SPI in any way. Software can abort the SPI transmission by clearing the SPE bit of the slave.

Note: A Logic 1 voltage on the $\overline{SS}$ pin of a slave SPI puts the MISO pin in a high impedance state. Also, the slave SPI ignores all incoming SCLK clocks, even if it was already in the middle of a transmission.

In a master SPI, the MODF flag will not be cleared until the $\overline{SS}$ pin is at a Logic 1 or the SPI is configured as a slave.

In a slave SPI, if the MODF flag is not cleared by writing 1 to the MODF bit, the condition causing the mode fault still exists. The MODF flag and corresponding interrupt can be cleared by disabling the EERIE or MODFEN bits (if set) or by disabling the SPI. It is possible to clear the MODF error condition by disabling the SPE or MODFEN bits. Disabling the SPI using the SPE bit will cause a partial reset of the SPI and may cause the loss of a message currently being received or transmitted.

To clear the MODF flag, write a one to the MODF bit in the SPSCR register. The clearing mechanism must occur with no MODF condition existing or else the flag is not cleared.

10.10 Module Memory Map

Four registers control and monitor SPI operations, and are provided in **Table 10-6.** These read/write registers should be accessed only with word accesses. Accesses other than word lengths result in undefined results.

Table 10-3. SPI Module Memory Map (SPI_BASE = $1FFFE8)

Address Offset	Register Acronym	Register Name	Access Type	Chapter Location
Base + $0	SPSCR	Status and Control Register	Read/Write	Section 10.11.1
Base + $1	SPDSCR	Data Size and Control Register	Read/Write	Section 10.11.2
Base + $2	SPDRR	Data Receive Register	*Read-Only*	Section 10.11.3
Base + $3	SPDTR	Data Transmit Register	*Write-Only*	Section 10.11.4

Add. Offset	Register Name		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$0	SPSCR	R	SPR			DSO	ERRIE	MODFEN	SPRIE	SPMSTR	CPOL	CPHA	SPE	SPTIE	SPRF	OVRF	MODF	SPTE
		W																
$1	SPDSCR	R	WOM	0	0	0	0	0	0	0	0	0	0	0	TDS			
		W																
$2	SPDRR	R	R15	R14	R13	R12	R11	R10	R9	R8	R7	R6	R5	R4	R3	R2	R1	R0
		W																
$3	SPDTR	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		W	T15	T14	T13	T12	T11	T10	T9	T8	T7	T6	T5	T4	T3	T2	T1	T0

R	0	Read as 0
W		Reserved

Figure 10-12. SPI Register Map Summary

10.11 Registers Descriptions (SPI_BASE = $1FFFE8)

Table 10-6 lists the SPI registers in ascending address, including the acronym, bit names, and address of each register. These read/write registers should be accessed only with word accesses. Accesses other than word lengths result in undefined results.

10.11.1 SPI Status and Control Register (SPSCR)

The SPSCR register:

- Enables SPI module interrupt requests
- Selects interrupt requests
- Configures the SPI module as Master or Slave
- Selects serial clock polarity and phase
- Enables the SPI module Receive Data Register full
- Fails to clear SPRF bit before next full length data is received (overflow error)
- Has inconsistent logic level on $\overline{SS}$ pin (mode fault error)
- Transmits Data Register Empty
- Selects Master SPI baud rate

Base + $0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	SPR			DSO	ERRIE	MODFEN	SPRIE	SPMSTR	CPOL	CPHA	SPE	SPTIE	SPRF	OVRF	MODF	SPTE
Write																
Reset	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0

Figure 10-13. SPI Status and Control Register (SPSCR)

See Programmer's Sheets on Appendix page B-49

Note: Using BFCLR or BFSET instructions to modify SPSCR can cause unintended side effects on the status bits.

10.11.1.1 SPI Baud Rate Select Bits (SPR)—Bits 15–13

While in the Master mode, these read/write bits select one of eight baud rates depicted in **Table 10-4.** SPR2:0 have no effect in Slave mode. Reset clears SPR2:0 to b011. Use the formula below to calculate the SPI baud rate.

SPR1 and SPR0 have no effect in Slave mode. Reset clears SPR1 and SPR0. Use the formula below to calculate the SPI baud rate.

$$\text{Baud Rate} = \frac{\text{CLK}}{\text{BD}}$$

CLK =Peripheral Bus Clock BD = Baud Rate Divisor

Table 10-4. SPI Master Baud Rate Selection

SPR[2:0]	Baud Rate Divisor (BD)
000	2
001	4
010	8
011	16
100	32
101	64
110	128
111	256

Note: The maximum data transmission rate for the SPI is typically limited by the bandwidth of the I/O drivers on the chip. Typical limits for our technologies are normal at 40MHz and 10MHz for Wired OR. These apply to both master and slave modes. The BD field needs to be set to keep the module within these ranges.

10.11.1.2 Data Shift Order (DSO)—Bit 12

This read/write bit determines whether the MSB or LSB bit is transmitted or received first. Both Master and Slave SPI modules must transmit and receive the same length packets. Regardless how this bit is set, when reading from the SPDRR or writing to the SPDTR, the LSB will always be at bit location zero. If the data length is less than 16 bits, the data will be zero padded on the upper bits.

- 0 = MSB transmitted first (MSB > LSB)
- 1 = LSB transmitted first (LSB > MSB)

10.11.1.3 Error Interrupt Enable (ERRIE)—Bit 11

This read/write bit enables the MODF and OVRF bits to generate interrupt requests. Reset clears the ERRIE bit. The Error Interrupt Enable (ERRIE) bit enables both the MODF and OVRF bits to generate a receiver/error interrupt request.

- 0 = MODF and OVRF cannot generate interrupt requests
- 1 = MODF and OVRF can generate interrupt requests

10.11.1.4 Mode Fault Enable (MODFEN)—Bit 10

This read/write bit, when set to 1, allows the MODF flag to be set. If the MODF flag is set, clearing the MODFEN does not clear the MODF flag.

If the MODFEN bit is low, the level of the $\overline{SS}$ pin does not affect the operation of an enabled SPI configured as a master. For an enabled SPI configured as a slave, having MODFEN low only prevents the MODF flag from being set. It does not affect any other part of SPI operation.

The Mode Fault Enable (MODFEN) bit can retard the MODF flag from being set. The retarded bit results in only the OVRF bit being enabled by the ERRIE bit. This enabling generates receiver/error interrupt requests.

10.11.1.5 SPI Receiver Interrupt Enable (SPRIE)—Bit 9

This read/write bit enables interrupt requests generated by the SPRF bit. The SPRF bit is set when a full data length transfers from the Shift Register to the Receive Data Register. The SPI Receiver Interrupt Enable (SPRIE) bit enables the SPRF bit to generate receiver interrupt requests regardless of the state of the SPE bit. The clearing mechanism for the SPRF flag is always just a read to the Receive Data Register.

- 0 = SPRF interrupt requests disabled
- 1 = SPRF interrupt requests enabled

10.11.1.6 SPI Master (SPMSTR)—Bit 8

This read/write bit selects Master mode operation or Slave mode operation.

- 0 = Slave mode
- 1 = Master mode (default)

10.11.1.7 Clock Polarity (CPOL)—Bit 7

This read/write bit determines the logic state of the SCLK pin between transmissions. To transmit data between SPI modules, the SPI modules must have identical CPOL values. Please see **Figure 10-5** and **Figure 10-7.**

10.11.1.8 Clock Phase (CPHA)—Bit 6

This read/write bit controls the timing relationship between the serial clock and SPI data. To transmit data between SPI modules, the SPI modules must have identical CPHA values. When CPHA = 0, the $\overline{SS}$ pin of the Slave SPI module must be set to Logic 1 between full length data transmissions.

10.11.1.9 SPI Enable (SPE)—Bit 5

This read/write bit enables the SPI module. Clearing SPE causes a partial reset of the SPI. When setting/clearing this bit, *no* other bits in the SPSCR should be changed. Failure to following this statement may result in spurious clocks.

- 0 = SPI module disabled
- 1 = SPI module enabled

10.11.1.10 SPI Transmit Interrupt Enable (SPTIE)—Bit 4

This read/write bit enables interrupt requests generated by the SPTE bit. SPTE is set when a full data length transfers from the Transmit Data Register to the Shift Register. The SPI Transmitter Interrupt Enable (SPTIE) bit enables the SPTE flag to generate transmitter interrupt requests, provided the SPI is enabled (SPE = 1). The clearing mechanism for the SPTE flag is always just a write to the Transmit Data Register.

- 0 = SPTE interrupt requests disabled
- 1= SPTE interrupt requests enabled

10.11.1.11 SPI Receiver Full (SPRF)—Bit 3

This *read-only* flag is set each time full length data transfers from the Shift Register to the Receive Data Register. SPRF generates an interrupt request if the SPRIE bit in the SPI Control Register is set also. This bit may not be cleared.

- 0 = Receive Data Register not full
- 1 = Receive Data Register full

10.11.1.12 Overflow (OVRF)—Bit 2

This *read-only* flag is set if software does not read the data in the Receive Data Register before the next full data enters the Shift Register. In an overflow condition, the data already in the Receive Data Register is unaffected, and the data shifted in last is lost. Clear the OVRF bit by reading the SPI Status and Control Register with OVRF set and then
reading the Receive Data Register. This bit may be cleared using the proper software sequence.

- 0 = No overflow
- 1 = Overflow

10.11.1.13 Mode Fault (MODF)—Bit 1

This *read-only* flag is set in a slave SPI if the $\overline{SS}$ pin goes high during a transmission with the MODFEN bit set. In a master SPI, the MODF flag is set if the $\overline{SS}$ pin goes low at any time with the MODFEN bit set. Clear the MODF bit by writing 1 to the MODF bit when it is set. The delayed bit results in only the OVRF interrupt being enabled by the ERRIE bit. This enabling generates receiver/error interrupt requests.

- 0 = $\overline{SS}$ pin at appropriate logic level
- 1 = $\overline{SS}$ pin at inappropriate logic level

10.11.1.14 SPI Transmitter Empty (SPTE)—Bit 0

This *read-only* flag is set each time the Transmit Data Register transfers a full data length into the Shift Register. SPTE generates an interrupt request if the SPTIE bit in the SPI Control Register is set also. This bit may be cleared using the proper software sequence.

- 0 = Transmit Data Register not empty
- 1 = Transmit Data Register empty

Note: Do not write to the SPI Data Register unless the SPTE bit is high.

10.11.2 SPI Data Size and Control Register (SPDSCR)

This read/write register determines the data length for each transmission. The master and slave must transfer the same size data on each transmission. A new value will only take effect at the time the SPI is enabled (SPE bit in SPSCR register set from zero to one). In order to have a new value take effect, disable then re-enable the SPI with the new value in the register. The SPDSCR:

- Enables Wired OR mode on SPMISO and SPIMOSI
- Configures the size of the transmission

Base +$1	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	WOM	0	0	0	0	0	0	0	0	0	0	0	TDS			
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1

Figure 10-14. SPI Data Size and Control Register (SPDSCR)

See Programmer's Sheet on Appendix page B-50

10.11.2.1 Wired OR Mode (WOM)—Bit 15

This control bit is used to select the nature of the SPI pins. When enabled, the WOM bit is set, the SPI pins are configured as open-drain drivers with the pull-ups disabled. However, when disabled, the WOM bit is cleared, and the SPI pins are configured as push-pull drivers.

- 0 = Wired OR mode disabled
- 1 = Wired OR mode enabled

10.11.2.2 Reserved—Bits 14-4

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

10.11.2.3 Transmission Data Size (TDS)—Bits 3-0

Please see **Table 10-5** for detailed transmission data.

Table 10-5. Transmission Data Size

DS3 - DS0	Size of Transmission
$0	Not Allowed
$1	2 Bits
$2	3 Bits
$3	4 Bits
$4	5 Bits
$5	6 Bits
$6	7 Bits
$7	8 Bits
$8	9 Bits
$9	10 Bits
$A	11 Bits
$B	12 Bits
$C	13 Bits
$D	14 Bits
$E	15 Bits
$F	16 Bits

10.11.3 SPI Data Receive Register (SPDRR)

This *read-only* register will show the last full data received after a complete transmission while the SPRF bit will set when new data has been transferred to this register.

Base + $2	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	R15	R14	R13	R12	R11	R10	R9	R8	R7	R6	R5	R4	R3	R2	R15	R0
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 10-15. SPI Data Receive Register (SPDRR)

See Programmer's Sheet on Appendix page B-51

10.11.3.1 Data Receive—Bits 15–0

10.11.4 SPI Data Transmit Register (SPDTR)

This *write-only* register modifies the data to the transmit data buffer. When the SPTE bit is set, new data should be written to this register. If new data is not written while in the Master mode, a new transaction will not be initiated until this register is written. When in Slave mode, the old data will be re-transmitted. All data should be written with the LSB at bit zero.

Base + $3	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Write	T15	T14	T13	T12	T11	T10	T9	T8	T7	T6	T5	T4	T3	T2	T1	T0
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 10-16. SPI Data Transmit Register (SPDTR)

See Programmer's Sheet on Appendix page B-52

10.11.4.1 Data Transmit—Bits 15–0

To clear the MODF flag, read the SPSCR with the MODF bit set and then write to the SPSCR Register. This entire clearing mechanism must occur with no MODF condition existing or else the flag is not cleared.

10.12 Resets

Any system reset completely resets the SPI. Partial resets occur whenever the SPI enable bit (SPE) is low. Whenever SPE is low, the following will occur:

- The SPTE flag is set.
- Any slave mode transmission currently in progress is aborted.
- Any master mode transmission currently in progress is continued to completion.
- The SPI state counter is cleared, making it ready for a new complete transmission.
- All the SPI port logic is disabled.

The following items are reset only by a system reset:

- The SPDTR and SPDRR Registers
- All control bits in the SPSCR Register (MODFEN, ERRIE, SPR1, and SPR0)
- The status flags SPRF, OVRF, and MODF

By not resetting the control bits when SPE is low, it is possible to clear SPE between transmissions without having to set all control bits again when SPE is set back high for the next transmission.

By not resetting the SPRF, OVRF, and MODF flags, it is possible to service the interrupts after the SPI has been disabled. Disable SPI by writing 0 to the SPE bit. SPI can also be disabled by a Mode Fault occurring in a SPI configured as a master with MODF.

10.13 Interrupts

Four SPI status flags can be enabled to generate interrupt requests.

Table 10-6. SPI Interrupts

Flag	Request
SPTE (Transmitter Empty)	SPI Transmitter Interrupt Request (SPTIE = 1,SPE = 1)
SPRF (Receiver Full)	SPI Receiver Interrupt Request (SPRIE = 1)
OVRF (Overflow)	SPI Receiver/Error Interrupt Request (ERRIE = 1)
MODF (Mode Fault)	SPI Receiver/Error Interrupt Request (ERRIE = 1)

The following sources in the SPI Status and Control Register can generate interrupt requests:

- The SPI Transmitter Interrupt Enable (SPTIE) bit enables the SPTE flag to generate transmitter interrupt requests provided the SPI is enabled (SPE = 1). The clearing mechanism for the SPTE flag is always just a write to the transmit data register.

- The SPI Receiver Interrupt Enable (SPRIE) bit enables the SPRF bit to generate receiver interrupt requests regardless of the state of the SPE bit. The clearing mechanism for the SPRF flag is always just a read to the Receive Data Register.
- The Error Interrupt Enable (ERRIE) bit enables both the MODF and OVRF bits to generate a receiver/error controller interrupt request.
- The Mode Fault Enable (MODFEN) bit can prevent the MODF flag from being set so only the OVRF bit is enabled by the ERRIE bit to generate receiver/error controller interrupt requests.

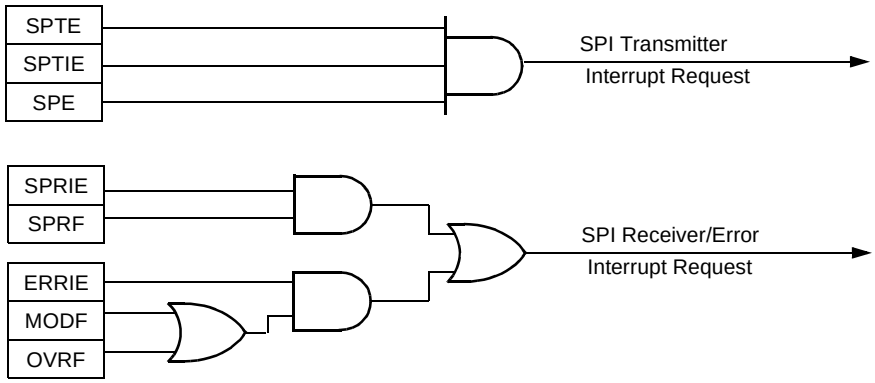


Figure 10-17. SPI Interrupt Request Generation

The following sources in the SPI Status and Control Register can generate interrupt requests:

- SPI Receiver Full (SPRF) — The SPRF bit becomes set every time a full data transmission transfers from the Shift Register to the Receive Data Register. If the SPI Receiver Interrupt Enable (SPRIE) bit is also set, SPRF can generate a SPI receiver/error interrupt request.
- SPI Transmitter Empty (SPTE) — The SPTE bit becomes set every time a full data transmission transfers from the Transmit Data Register to the Shift Register. If the SPI Transmit Interrupt Enable (SPTIE) bit is also set, SPTE can generate a SPTE interrupt request.

Chapter 11
Improved Synchronous Serial Interface (ISSI)

11.1 Introduction

This chapter describes the Improved Synchronous Serial Interface (ISSI), by discussing the architecture, programming model, operating modes, and initialization of the ISSI. The ISSI is a full-duplex, serial port allowing Digital Signal Controller (DSCs) to communicate with a variety of serial devices, including industry-standard codecs, other DSCs, microprocessors, and peripherals implementing the Serial Peripheral Interface (SPI). It is typically used to transfer samples in a periodic manner. The ISSI consists of independent transmitter and receiver sections with independent clock generation and frame synchronization.

11.2 Features

ISSI features include:

- Independent (asynchronous) or shared (synchronous) transmit and receive sections with separate or shared internal/external clocks and frame syncs
- Normal mode operation using frame sync
- Network mode operation allowing multiple devices to share the port with as many as thirty-two time-slots
- Gated Clock mode operation requiring no frame sync
- Programmable internal clock divider
- Programmable word length (8, 10, 12, or 16 bits)
- Program options for frame sync and clock generation
- ISSI power down feature

11.3 Signal Descriptions

11.3.1 Signal Properties

Table 11-1. Signal Properties

Name	I/O Type	Function	Reset State	Notes
STCK	I/O	ISSI Transmit Clock	Input	Controlled by reset state of TXDIR bit in STXCR
STFS	I/O	ISSI Transmit Frame Sync	Input	Controlled by reset state of TFDIR bit in SOR
SRCK	I/O	ISSI Receive Clock	Input	Controlled by reset state of RXDIR bit in STXCR
SRFS	I/O	ISSI Receive Frame Sync	Input	Controlled by reset state of RFDIR bit in SOR
STX	Output	ISSI Transmit Data	High Z	Since ISSIEN bit of STXCR is reset to 0
SRX	Input	ISSI Receive Data	—	—

11.3.2 External Signal Descriptions

11.3.2.1 ISSI Transmit Clock (STCK)

This pin can be configured as either an input or an output pin. This clock signal is used by the transmitter. It can be either continuous or gated. During Gated Clock mode, the STCK pin is active only during the transmission of data, otherwise it is inactive (low). In the Synchronous mode, this pin is used by both the transmit and receive sections.

11.3.2.2 ISSI Transmit Frame Sync (STFS)

This pin can be configured as either an input or an output pin. The frame sync is used by the transmitter to synchronize the transfer of data. The frame sync signal can be one bit or one word in length. The start of the frame sync can occur one bit before the transfer of data or right at the start of the data transfer.

In the Synchronous mode this pin is used by both the transmit and receive sections. Frame sync signals are not used in the Gated Clock mode.

11.3.2.3 ISSI Receive Clock (SRCK)

This pin can be configured as either an input or an output pin. This clock signal is used by the receiver. It can be either continuous or gated. During the Gated Clock mode, the STFS pin is active only during the reception of data, otherwise it is inactive, or low.

In the Synchronous mode, this pin is not used and can be configured as a GPIO pin.

11.3.2.4 ISSI Receive Frame Sync (SRFS)

This pin can be configured as either an input or an output pin. The frame sync is used by the receiver to synchronize the transfer of data. The frame sync signal can be one bit or one word in length. The start of the frame sync can occur one bit before the transfer of data or right at the start of the data transfer.

In the Synchronous mode, this pin is not used and can be configured as a GPIO pin.

11.3.2.5 ISSI Transmit Data (STX)

This pin transmits data from the Serial Transmit Shift Register (STSR). The STXD pin is an output pin when data is being transmitted. It is inactive (High-Z) between data word transmissions.

11.3.2.6 ISSI Receive Data (SRX)

This pin is used to bring serial data into the Receive Data Shift Register (RXSR).

11.4 Block Diagram

The ISSI block diagram is detailed in **Figure 11-1.** The diagram consists of:

- Three control registers to set up the port
- One status/control register
- Separate transmit and receive circuits with FIFO registers
- Separate serial clock and frame sync generation for the transmit and receive sections

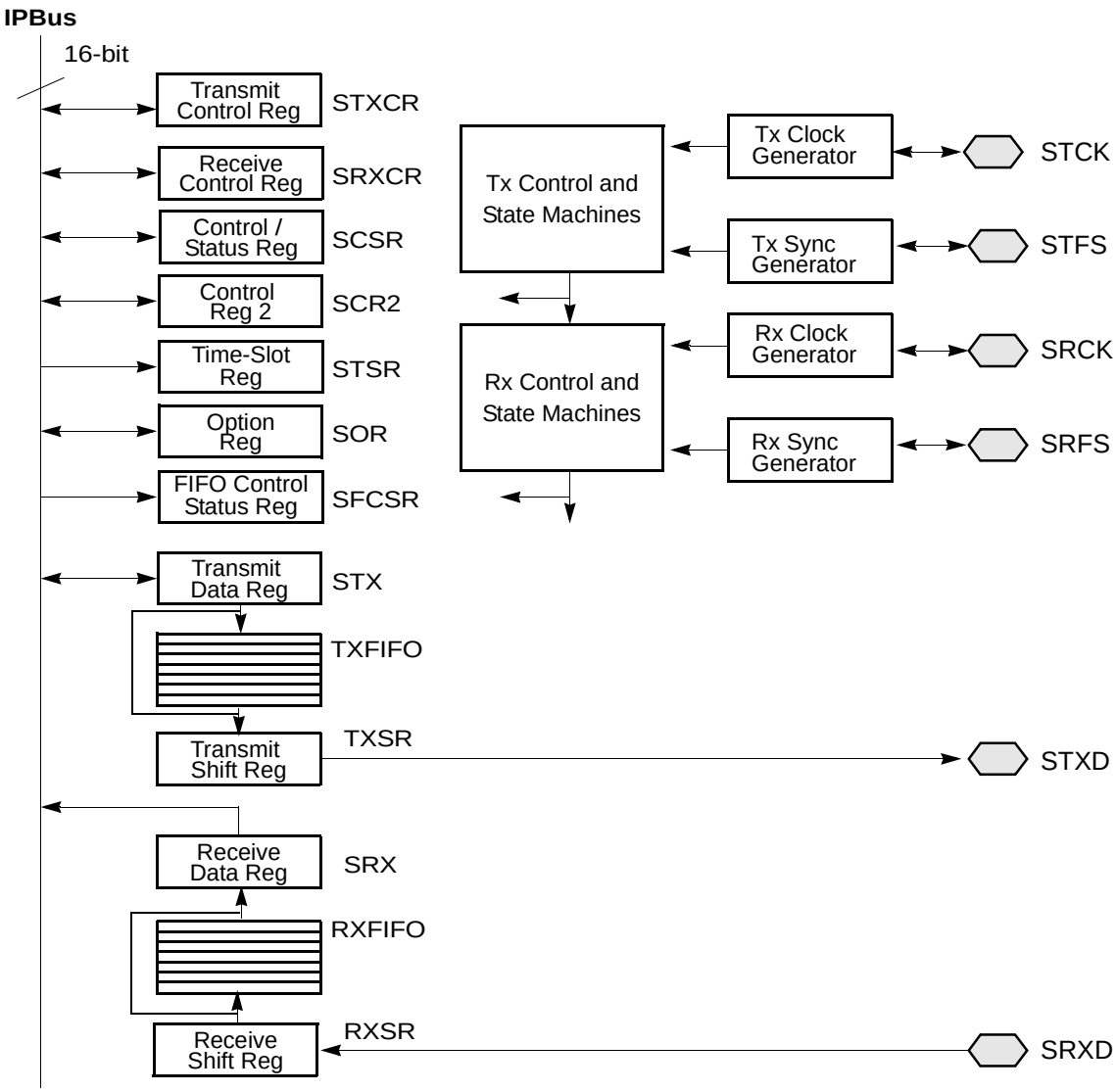


Figure 11-1. ISSI Block Diagram

11.5 ISSI Configurations

Figure 11-21 and **Figure 11-22** illustrate the main ISSI configurations. These pins support all transmit and receive functions with continuous or gated clock as shown. **Table 11-5** describes the clock, frame sync, and data timing relationships in each of the modes available. Note gated clock implementations do not require the use of the frame sync pins. In this case, these pins can be used as GPIO pins, if desired.

Note: The GPIO is a separate module, and alternatively controls the function and state of the I/O pins. Please see the GPIO module definition for alternate functions of the I/O pins defined here.

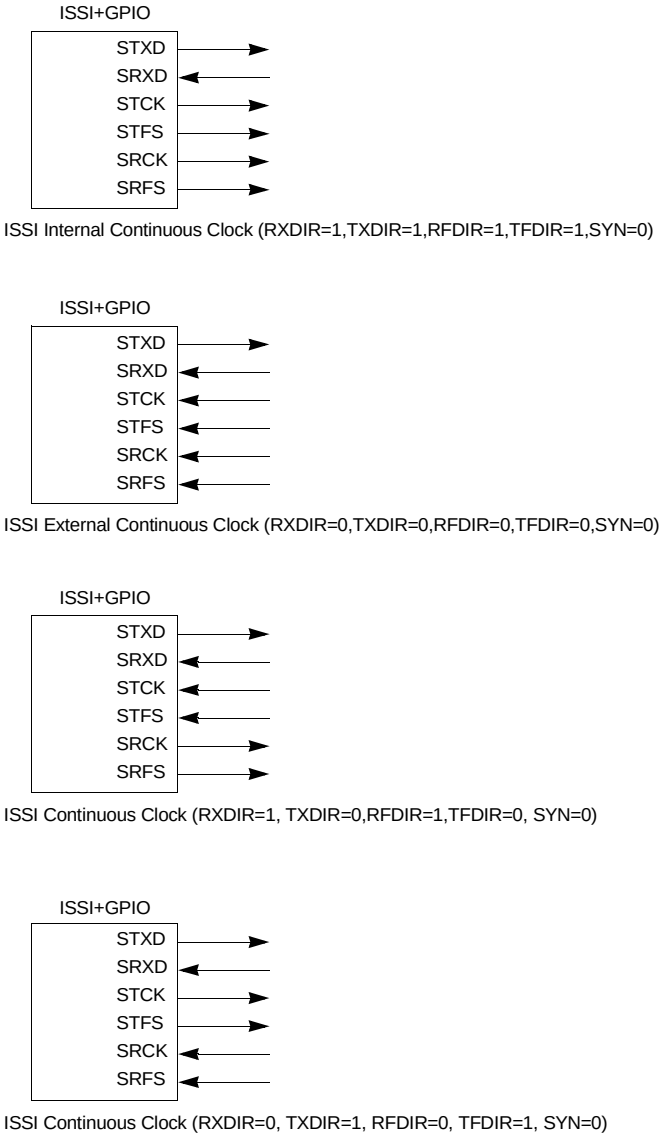
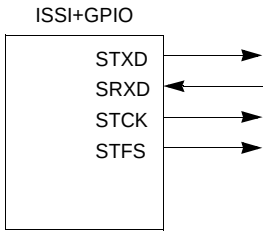
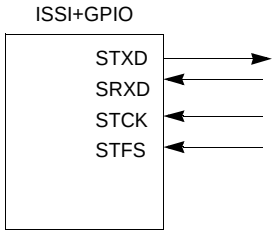


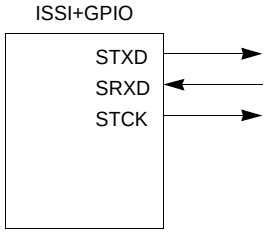
Figure 11-2. Asynchronous (SYN=0) ISSI Configurations—Continuous Clock



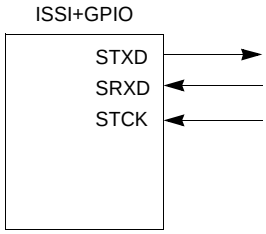
ISSI Internal Continuous Clock (RXDIR=0, TXDIR=1, RFDIR=X, TFDIR=1, SYN=1)



ISSI External Continuous Clock (RXDIR=0, TXDIR=0, RFDIR=X, TFDIR=0,SYN=1)



ISSI Internal Gated Clock (RXDIR=1, TXDIR=1, SYN=1)



ISSI External Gated Clock (RXDIR=1, TXDIR=0, SYN=1)

Figure 11-3. Synchronous ISSI Configurations—Continuous and Gated Clock

11.6 Module Memory Map

Table 11-2 details the ISSI memory map. Please note there are four *inaccessible* registers.

Table 11-2. ISSI Module Memory Map (ISSI_BASE = $1FFE20)

Address Offset	Register Acronym	Register Name	Access Type	Chapter Location
Base + $0	STX	Transmit Data	Read/Write	**Section 11.7.1**
Base + $1	SRX	Receive Data	*Read-Only*	**Section 11.7.4**
Base + $2	SCSR	Control/Status Register	*Read-only in lower bytes*	**Section 11.7.8**
Base + $3	SCR2	Control Register 2	Read/Write	**Section 11.7.9**
Base + $4	STXCR	Transmit Control Register	Read/Write	**Section 11.7.7**
Base + $5	SRXCR	Receive Control Register	Read/Write	
Base + $6	STSR	Time-Slot Register	*Write-Only*	**Section 11.7.10**
Base + $7	SFCSR	FIFO Control/Status Register	*Read-Only*	**Section 11.7.11**
Base + $9	SOR	Option Register	Read/Write	**Section 11.7.12**

Add. Offset	Register Name		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$0	STX	R	DATA															
		W																
$1	SRX	R	HIGH BYTE								LOW BYTE							
		W																
$2	SCSR	R	DIV4DIS	RSHFD	RSCKP	RDMAE	TDMAE	RFSI	RFSL	REFS	RDR	TDE	ROE	TUE	TFS	RFS	RFF	TFE
		W																
$3	SCR2	R	RIE	TIE	RE	TE	RFEN	TFEN	RXDIR	TXDIR	SYN	TSHFD	TSCKP	ISSIEN	NET	TFSI	TFSL	TEFS
		W																
$4	STXCR	R	PSR	WL		DC					PM							
		W																
$5	SRXCR	R	PSR	WL		DC					PM							
		W																
$6	STSR	R																
		W	DUMMY REGISTER, WRITTEN DURING INACTIVE TIME-SLOTS (NETWORK MODE)															
$7	SFCSR	R	RFCNT				TFCNT				RFWM				TFWM			
		W																
$9	SOR	R	0	0	0	0	0	0	0	0	0	0	RFDIR	TFDIR	0	0	0	0
		W																

R 0 Read as 0
W Reserved

Figure 11-4. ISSI Register Map Summary

11.7 Register Descriptions (ISSI_BASE = $1FFE20)

11.7.1 ISSI Transmit Data Register (STX)

The STX Register is a 16-bit, read/write register. Data to be transmitted is written into this register. If the Transmit FIFO is enabled, data is transferred from this register to the Transmit FIFO Register when the FIFO can accommodate the data. Otherwise, data written to this register is transferred to the Transmit Shift Register (TXSR) when shifting of previous data is completed. The written data occupies the most significant portion of the STX Register. Unused bits, the least significant portion of the STX Register, are ignored.

If the transmit interrupt is enabled, the interrupt is asserted when the STX Register becomes empty (TDE = 1). When the transmit FIFO is also enabled, the transmit FIFO must be below its watermark for the interrupt to assert.

Note: Enable ISSI (ISSI_EN = 1) before writing to STX.

Base + $0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	DATA															
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 11-5. ISSI Transmit Data Register (STX)

See Programmer's Sheet on Appendix page B - 53

11.7.2 ISSI Transmit FIFO Register (TXFIFO)

The TXFIFO is a 8 × 16-bit register used to buffer samples written to the ISSI Transmit Data (STX) register. It is written by the contents of STX whenever the transmit FIFO feature is enabled. When enabled, the Transmit Shift Register (TXSR) receives its values from this FIFO Register. If the transmit FIFO feature is not enabled, this register is bypassed and the contents of STX are transferred into the TXSR.

When the Transmit Interrupt Enable (TIE) bit in the SCR2 and Transmit Data Empty (TDE) Register bit in the SCSR are set, the transmit interrupt is asserted whenever STX is empty and the data level in the ISSI transmit FIFO falls below the selected threshold.

When both TXFIFO and STX are full, any further write will over-write the content of TXFIFO and STX.

Note: Enable ISSI before writing to TXFIFO and STX.

11.7.3 ISSI Transmit Shift Register (TXSR)

TXSR is a 16-bit Shift Register. It contains data being transmitted. When a continuous clock is used, data is shifted out to the Serial Transmit Data (STX) pin by the selected (internal/external) bit clock when the associated (internal/external) frame sync is asserted.

When a gated clock is used, data is shifted out to the STXD pin by the selected (internal/external) gated clock. The Word Length (WL) control bits in the SSI Transmit Control Register (STXCR) determines the number of bits to be shifted out of the TXSR before it is considered empty, and before it can be written to again. Please refer to **Section 11.7.7** for more information. Word length can be 8, 10, 12, or 16 bits. The data to be transmitted occupies the most significant portion of the Shift Register. The unused portion of the register is ignored. Data is always shifted out of this register with the Most Significant Bit (MSB) first, and upon the SHFD bit of the SCR2 being cleared. If this bit is set, the Least Significant Bit (LSB) is shifted out first.

Please see **Figure 11-9** and **Figure 11-10** for more information.

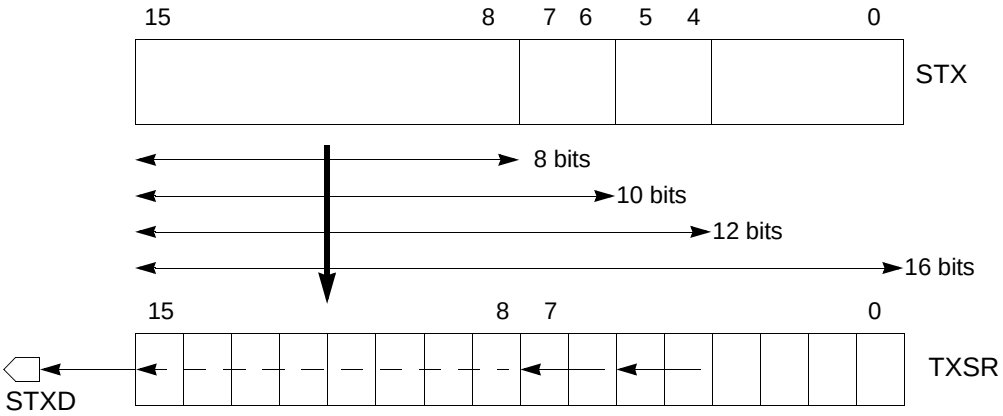


Figure 11-6. Transmit Data Path (TSHFD = 0)

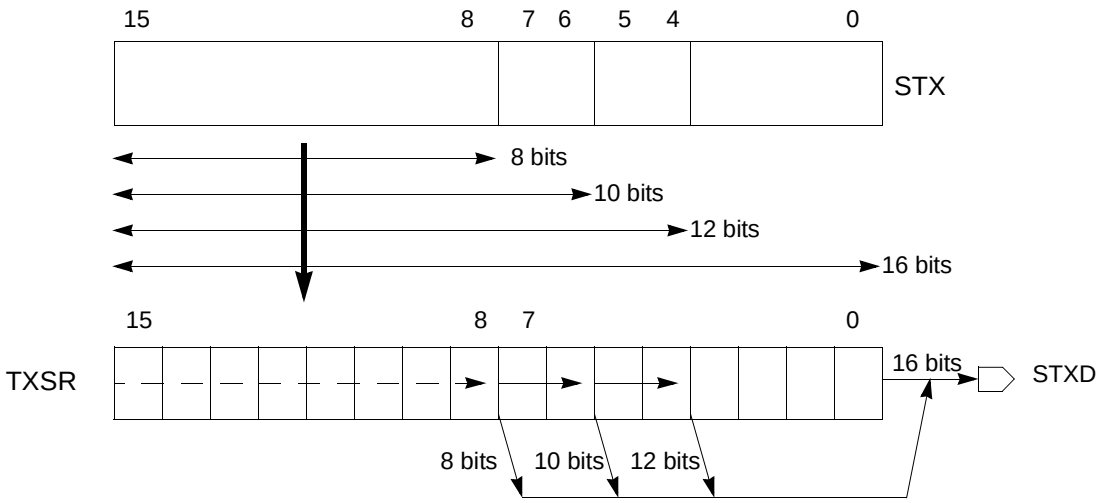


Figure 11-7. Transmit Data Path (TSHFD = 1)

11.7.4 ISSI Receive Data Register (SRX)

The SRX is a 16-bit, *read-only* register. It always accepts data from the Receive Shift Register (RXSR) as it becomes full. The data read occupies the most significant portion of the SRX Register. Unused bits, least significant portion, are read as zeros.

If the Receive Data Full interrupt is enabled, the interrupt is asserted whenever the SRX Register becomes full. If the receive FIFO is also enabled, the receive FIFO must be above its watermark before the interrupt is asserted.

Base + $1	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	HIGH BYTE								LOW BYTE							
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 11-8. ISSI Receive Data Register (SRX)

See Programmer's Sheet on Appendix page B - 54

11.7.5 ISSI Receive FIFO Register (RXFIFO)

The RXFIFO is a 8 × 16-bit FIFO Register used to buffer samples received in the ISSI Receive Data Register (SXR). The receive FIFO is enabled by setting the RFEN bit of the SCR2. Received data is then held in the FIFO if the data in the SRX has not yet been read.

If the Receive Interrupt is enabled, it is asserted whenever the SRX is full and the data level in the ISSI receive FIFO reaches the selected threshold. However, if the receive FIFO feature is not enabled, this register is bypassed and the Receive Shift Data Register (RXSR) data is automatically transferred into the SRX.

11.7.6 ISSI Receive Shift Register (RXSR)

RXSR is a 16-bit Shift Register. It receives incoming data from the Serial Receive Data (SRXD) pin. When a continuous clock is used, data is shifted in by the selected (internal/external) bit clock when the associated (internal/external) frame sync is asserted. When a gated clock is used, data is shifted in by the selected (internal/external) gated clock. Data is assumed to be received MSB first if the SHFD bit of the SCR2 is cleared. When this bit is set, the data is received LSB first. Data is transferred to the ISSI Receive Data (SRX) Register, or receive FIFO (if the receive FIFO is enabled and SRX is full) after 8, 10, 12, or 16 bits have been shifted in depending on the WL control bits. For receiving 8, 10, or 12 bits data, LSB bits are set to 0.

Please refer to **Figure 11-12** and **Figure 11-13** for more information.

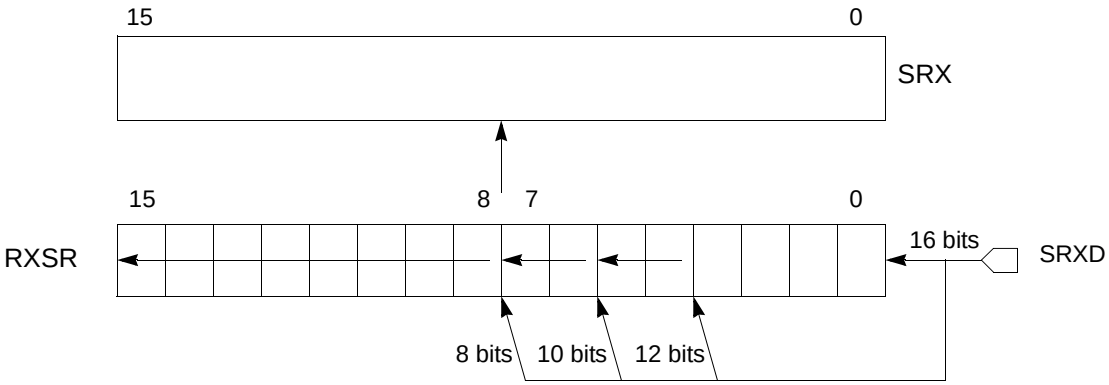


Figure 11-9. Receive Data Path (RSHFD=0)

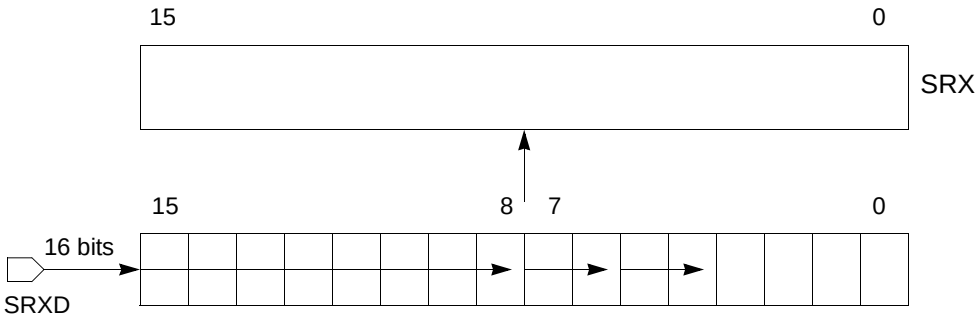


Figure 11-10. Receive Data Path (RSHFD=1)

11.7.7 ISSI Transmit and Receive Control Registers (STXCR, SRXCR)

STXCR and SRXCR are 16-bit, read/write control registers used to direct the operation of the ISSI. These registers control the ISSI clock generator bit and frame sync rates, word length, and number of words per frame for the serial data. The STXCR is dedicated to the transmit section. The SRXCR is dedicated to the receive section except in the Synchronous mode, where the STXCR controls both the receive and transmit sections. Power-On Reset clears all STXCR and SRXCR bits. ISSI reset does not affect the STXCR and SRXCR bits.

The control bits are described in the following paragraphs. Although the bit patterns of the SRXCR and SCTRX Registers are the same, the contents of these two registers can be programmed differently.

Base + $4	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	PSR	WL		DC					PM							
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 11-11. SSI Transmit Control Register (STXCR)

See Programmer's Sheet on Appendix page B - 55

Base + $5	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	PSR	WL		DC					PM							
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 11-12. ISSI Receive Control Register (SRXCR)

See Programmer's Sheet on Appendix page B - 56

11.7.7.1 Prescaler Range (PSR)—Bit 15

This bit controls a fixed divide-by-eight prescaler in series with the variable prescaler. It extends the range of the prescaler for those cases where a slower bit clock is desired.

When the PSR bit is set, the fixed divide-by-eight prescaler is operational. This allows a 128kHz master clock to be generated for MC1440x series codecs. The maximum internally generated bit clock frequency is $F_{IP\_CLK}/(2x2)$ and the minimum internally generated bit clock frequency is $F_{IP\_CLK}/(4 \times 2 \times 8 \times 256 \text{ x } 2)$.

When the PSR bit is cleared, the fixed prescaler is bypassed.

11.7.7.2 Word Length Control (WL)—Bits 14–13

This bit field is used to select the length of the data words being transferred by the ISSI. Word lengths of 8, 10, 12, or 16 bits can be selected. **Table 11-3** depicts WL bit field encoding.

Table 11-3. WL Encoding

WL[1:0]	Number of Bits/Word
00	8
01	10
10	12
11	16

These bits control the Word Length Divider shown in the ISSI Clock Generator. The WL control bits also control the frame sync pulse length when the TFSL bit is cleared.

11.7.7.3 Frame Rate Divider Control (DC)—Bit 12–8

This bit field controls the divide ratio for the programmable frame rate dividers. The divide ratio operates on the word clock.

In the Normal mode, this ratio determines the word transfer rate. The divide ratio ranges from one to 32 (DC = 00000 to 11111) in the Normal mode. A divide ratio of one (DC=00000) provides continuous periodic data word transfer. A bit-length sync must be used in this case.

In the Network mode, this ratio sets the number of words per frame. The divide ratio ranges from two to 32 (DC = 00001 to 11111) in the Network mode. A divide ratio of one (DC=00000) in the Network mode is a special case, in the Demand mode. It is not supported in this implementation.

11.7.7.4 Prescaler Modulus Select (PM)—Bits 7–0

This bit field specifies the divide ratio of the prescale divider in the SSI clock generator. This prescaler is used only in Internal Clock mode to divide the internal clock of the core. A divide ratio from one to 256 (PM = $00 to $FF) can be selected. The bit clock output is available at the STCK or SRCK clock pins. The bit clock on the SSI can be calculated from the peripheral clock value using the following equation:

$$f_{FIX\_CLK} = f_{IP\_Bus\_CLK}/4 \text{ if DIV4DIS} = 0$$

$$f_{FIX\_CLK} = f_{IP\_Bus\_CLK} \text{ if DIV4DIS} = 1$$

$$f_{INT\_BIT\_CLK} = f_{FIX\_CLK}/[4 \times (7 \times PSR + 1) \times (PM + 1)] \text{ where PM} = PM[7:0]$$

$$f_{FRAME\_SYN\_CLK} = (f_{INT\_BIT\_CLK})/[(DC + 1) \times WL] \text{ where DC} = DC[4:0] \text{ and WL} = 8, 10, 12, \text{ or } 16$$

For example, with 8-bit words operating in the Normal mode, if an 8kHz sampling rate is desired the following parameters can be used:

$f_{IP\_Bus\_CLK} = f_{SYSTEM\_CLK} / 2 = 120MHz / = 60MHz$

$f_{FIX\_CLK} = f_{IP\_Bus\_CLK} = 60MHzDIV4DIS = 1$

$f_{INT\_BIT\_CLK} = f_{FIX\_CLK}/[4 \times (7 \times PSR + 1) \times (PM + 1)]= 60MHz / [4 \times 1 \times 117] = 128.2kHzPS = 0, PM = 116$

$f_{FRAME\_SYN\_CLK} = (f_{INT\_BIT\_CLK})/[(DC + 1) \times WL]DC = 1 = 128kHz / [2 \times 8] = 8.012kHz$

The bit clock output is also available internally for use as the bit clock to shift the transmit and Receive Shift Registers. Careful choice of the crystal oscillator frequency and the prescaler modulus allows the telecommunication industry standard codec master clock frequencies of 2.048MHz, 1.544MHz, and 1.536MHz to be generated. For example, a 24.576MHz clock frequency can be used to generate the standard 2.048MHz and 1.536MHz rates, and a 24.704MHz clock frequency can be used to generate the standard 1.544MHz rate. **Table 11-4** provides examples of PM values. These values can be used to generate different bit clocks.

Table 11-4. SSI Bit Clock As a Function Of Peripheral Clock and Prescale Modulus

ip_clk (MHz)	fix_clk= ip_clk/4 (MHz)	Max Bit Clock, fix_clk/ 4 (MHz)	PM[7:0] Values For Different SCK					
			2.048 MHz	1.544 MHz	1.536 MHz	128kHz (PSR=0)	64kHz (PSR=0)	8kHz (PSR=1)
65.536	16.384	4.096	1	—	—	31 ($1F)	63 ($3F)	63 ($3F)
73.728	18.432	4.608	—	—	2	35 ($23)	71 ($47)	71 ($47)
81.920	20.480	5.12	—	—	—	39 ($27)	79 ($4F)	79 ($4F)
106.496	26.624	6.656	—	—	—	51 ($33)	103 ($67)	103 ($67)
98.304	24.576	6.144	2	—	3	47 ($2F)	95 ($5F)	95 ($5F)
98.816	24.704	6.176	—	3	—	—	—	—
—	32.768	8.192	3	—	—	63 ($3F)	127 ($7F)	127 ($7F)
—	36.864	9.216	—	—	5	71 ($47)	143 ($8F)	143 ($8F)

11.7.8 ISSI Control/Status Register (SCSR)

The SCSR is a 16-bit register used to set-up and monitor the ISSI. The top half of the register (bits [15:8]) is the read/write portion. It is used for ISSI set-up. The bottom half of the register (bits [7:0]) is *read-only*. It is used to interrogate the status and serial input flags of the ISSI. The control and status bits are described in the following paragraphs.

Note: ISSI Status flag is updated when SSI is enabled.

Note: All the flags in the status portion of the SCSR are updated after the first bit of the next ISSI word has completed transmission or reception. Receiver Overrun (ROE) and Transmitter Underrun Error (TUE) status bits are cleared by reading the SCSR followed by a read or write to either the SRX or STX Registers.

Base + $2	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	DIV4DIS	RSHFD	RSCKP	0	0	RFSI	RFSL	REFS	RDR	TDE	ROE	TUE	TFS	RFS	RFF	TFE
Write																
Reset	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1

Figure 11-13. ISSI Control/Status Register (SCSR)

See Programmer's Sheet on Appendix page B - 57

11.7.8.1 Divider 4 Disable (DIV4DIS)—Bit 15

- 0 = FIX_CLK = IP_CLK/4 for both transmitter and receiver clock generator circuits
- 1 = FIX_CLK is equal to IP_CLK

11.7.8.2 Receive Shift Direction (RSHFD)—Bit 14

This bit controls whether the MSB or LSB is received first as the receive section. If the RSHFD bit is cleared, data is received MSB first. When the RSHFD bit is set, the LSB is received first.

Note: The codec device labels the MSB as bit zero, whereas the SSI labels the LSB as bit zero. Therefore, when using a standard codec, the SSI MSB (or codec bit 0) is shifted out first, and the RSHFD bit should be cleared.

11.7.8.3 Receive Clock Polarity (RSCKP)—Bit 13

This bit controls which bit clock edge is used to latch in data for the receive section.

- 0 = The data is captured in on the falling edge of the clock
- 1 = The rising edge of the clock is used to captured the data in

11.7.8.4 Reserved—Bits 12–11

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

11.7.8.5 Receive Frame Sync Invert (RFSI)—Bit 10

This bit selects the logic of frame sync I/O for the receive section.

- 0 = The frame sync is active high
- 1 = The frame sync is active low

11.7.8.6 Receive Frame Sync Length (RFSL)—Bit 9

This bit selects the length of the frame sync signal to be generated or recognized for the receive section. Please see **Figure 11-14** for an example timing diagram of the FS options.

- 0 = A one word-long frame sync is selected
- 1 = A one clock bit-long frame sync is selected

The length of a word-long frame sync is the same as the length of the data word selected by WL.

11.7.8.7 Receive Early Frame Sync (REFS)—Bit 8

This bit controls when the frame sync is initiated for the receive section. Please refer to **Figure 11-14** for an example timing diagram of the FS options.

- 0 = When the REFS bit is cleared, the frame sync is initiated as the first bit of data is received.
- 1 = The frame sync is initiated one bit prior to received data. The frame sync is disabled after one bit-for-bit length frame sync and after one word-for-word length frame sync.

11.7.8.8 Receive Data Ready Flag (RDR)—Bit 7

This flag bit is set when Receive Data (SRX) Register, or Receive FIFO (RXFIFO) is loaded with a new value.

RDR is cleared when the CPU reads the SRX Register. If RXFIFO is enabled, RDR is cleared when receive FIFO is empty.

When the RIE bit is set, a receive data interrupt request is issued when the RDR bit is set. The interrupt request vector depends on the state of the Receiver Overrun (ROE) bit (in the SCSR). The RDR bit is cleared by POR and SSI reset.

11.7.8.9 Transmit Data Register Empty (TDE)—Bit 6

This flag bit is set when there is no data waiting to be transferred to the TXSR. If the Transmit FIFO (TXFIFO) is enabled, this occurs when there is at least one empty slot in STX or TXFIFO. If the TXFIFO is not enabled, this occurs when the STX is empty. That is, when the contents of the STX Register are transferred into the Transmit Shift Register (TXSR). When set, the TDE bit indicates data should be written to the STX Register or to the STSR before the TXSR becomes empty, or an underrun error will occur.

The TDE bit is cleared when data is written to the STX Register or to the STSR to disable transmission of the next time-slot. If the TIE bit is set, an ISSI transmit data interrupt request is issued when the TDE bit is set. The vector of the interrupt depends on the state of the TUE bit (in the SCSR). The TDE bit is set by power-on and ISSI reset.

11.7.8.10 Receive Overrun Error (ROE)—Bit 5

This flag bit is set when the Receive Shift Register (RXSR) is filled and ready to transfer to the SRX Register or the RXFIFO Register (when enabled). These registers are already full. If the receive FIFO is enabled, it is indicated by the Receive FIFO Full (RFF) bit. This is indicated by the Receive Data Ready (RDR) bit being set. The RXSR is not transferred in this case.

Note: When using the RXFIFO with a watermark other than eight, the ROE bit does not mean data has been lost. The RXCNT field of the SFCSR should be checked to determine the likelihood of actual data loss.

A receive overrun error does not cause interrupts. However, when the ROE bit is set, it causes a change in the interrupt vector used, allowing the use of a different interrupt handler for a receive overrun condition.

If a receive interrupt occurs with the ROE bit set, the receive data with exception status interrupt is generated. If a receive interrupt occurs with the ROE bit cleared, the receive data interrupt is generated. The ROE bit is cleared by power-on or ISSI reset. It is cleared by reading the SCSR with the ROE bit set, followed by reading the SRX Register. Clearing the RE bit does not affect the ROE bit.

11.7.8.11 Transmitter Underrun Error (TUE)—Bit 4

This flag bit is set when the TXSR is empty (no data to be transmitted), as indicated by the TDE bit being set, and a transmit time-slot occurs. When a transmit underrun error occurs, the previously sent data is retransmitted.

A transmit time-slot in the Normal mode occurs when the frame sync is asserted. In the Network mode, each time-slot requires data transmission. Therefore, the time-slot may cause a TUE error.

The TUE bit does not cause interrupts. However, the TUE bit does cause a change in the interrupt vector used for transmit interrupts resulting in a different interrupt handler being used for a transmit underrun condition. If a transmit interrupt occurs with the TUE bit set, the transmit data with exception status interrupt is generated. If a transmit interrupt occurs with the TUE bit cleared, the transmit data interrupt is generated.

The TUE bit is cleared by power-on or ISSI reset. The TUE bit is also cleared by reading the SCSR with the TUE bit set, followed by writing to the STX Register or to the STSR.

11.7.8.12 Transmit Frame Sync (TFS)—Bit 3

When set, this flag bit indicates a frame sync occurred during transmission of the last word written to the STX Register. As shown in **Figure 11-14,** data written to the STX Register during the time-slot when the TFS bit is set is transmitted during the second time-slot (in the Network mode) or in the next first time-slot (in the Normal mode). While in the Network mode, the TFS bit is set during transmission of the first slot of the frame. It is then cleared when starting transmission of the next slot. The TFS bit is cleared by power-on or ISSI reset.

11.7.8.13 Receive Frame Sync (RFS)—Bit 2

When set, this flag bit indicates a frame sync occurred during receiving of the next word into the SRX Register, as shown in **Figure 11-14.** While in the Network mode, the RFS bit is set as the first slot of the frame is being received. It is cleared when the next slot of the frame begins to be received. The RFS bit is cleared by power-on or ISSI reset.

11.7.8.14 Receive FIFO Full (RFF)—Bit 1

This flag bit is set when the receive section is programmed with the receive FIFO enabled, and the data level in the RXFIFO reaches the selected Receive FIFO WaterMark (RFWM) threshold. When set, RFF indicates data can be read via the SRX Register.

Note: An interrupt is only generated if both the RFF and RIE bits are set if RXFIFO is enabled.

The RFF bit is cleared in normal operation by reading the SRX Register. The RFF is also cleared by Power-On Reset or disabling the ISSI.

When RXFIFO is completely full, all further received data is ignored until data is read.

11.7.8.15 Transmit FIFO Empty (TFE)—Bit 0

This flag bit is set when the transmit section is programmed with the TXFIFO enabled and the data level in the TXFIFO falls below the selected Transmit FIFO WaterMark (TFWM) threshold. When set, the TFE bit indicates data can be written to the TXFIFO Register. The TFE bit is cleared by writing data to the STX Register until the TXFIFO data content level reaches the watermark level.

Note: An interrupt is generated only if both the TFE and the TIE bits are set if transmit FIFO is enabled.

The TFE bit is set by Power-On Reset (POR) and when ISSI is disabled.

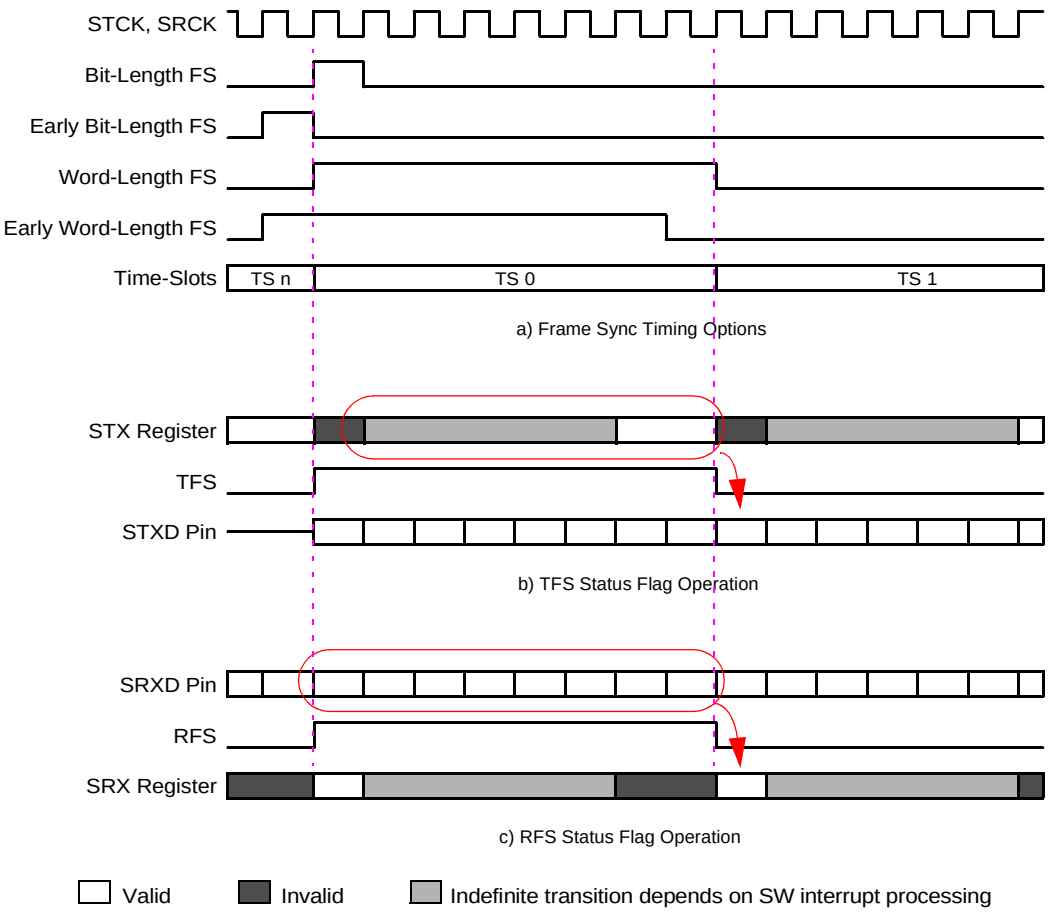


Figure 11-14. Frame Sync Timing Options

11.7.9 ISSI Control Register 2 (SCR2)

SCR2, one of three 16-bit control registers, selects the Operating mode for the ISSI.

Interrupt enable bits for the receive and transmit sections are provided in this control register. Before they can function the chip level Interrupt Priority Register (IPR) must be set to enable SSI interrupts.

Power-On Reset clears all SCR2 bits. However, SSI reset does not affect the SCR2 bits. The SCR2 bits are described in the following paragraphs.

Base + $3	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	RIE	TIE	RE	TE	RFEN	TFEN	RXDIR	TXDIR	SYN	TSHFD	TSCKP	ISSIEN	NET	TFSI	TFSL	TEFS
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 11-15. ISSI Control Register 2 (SCR2)

See Programmer's Sheet on Appendix page B - 59

11.7.9.1 Receive Interrupt Enable (RIE)—Bit 15

This control bit allows interrupting the program controller. When the RIE and RE bits are set, the program controller is interrupted when the ISSI receives data. As shown in **Table 11-4,** the interrupt trigger depends on whether the receive FIFO is enabled.

If the receive FIFO is disabled:

- 0 = No interrupt is generated.
- 1 = An interrupt is generated when the RDR flag (in the SCSR) is set. One value can be read from the SRX Register. Reading the SRX Register clears the RDR bit, thus clearing the interrupt.

If the receive FIFO is enabled:

- 0 = No interrupt is generated
- 1 = An interrupt is generated when the RFF flag (in the SCSR) is set. A maximum of eight values are available to be read from the SRX Register. Reading the SRX Register to remove data from the receive FIFO allowing the level to fall below the watermark clearing the RFF bit, thus clearing the interrupt.

Two receive data interrupts with separate interrupt vectors are available: receive data with exception status, and receive data without exception. **Table 11-5** illustrates these vectors and the conditions under which these interrupts are generated.

Table 11-5. ISSI Receive Data Interrupts[1]

Interrupt	RIE	Selection Control		ROE
		RFEN = 0	RFEN = 1	
Receive Data with Exception Status	1	RDR = 1	RFF = 1	1
Receive Data (without exception)	1	RDR = 1	RFF = 1	0

1. See **Table 11-23** for a complete list of interrupts.

11.7.9.2 Transmit Interrupt Enable (TIE)—Bit 14

This control bit allows interrupting the program controller. When the TIE and TE bits are set, the program controller is interrupted when the ISSI needs more transmit data. **Table 11-6** exhibits the interrupt trigger depends on whether the transmit FIFIO is enabled.

If the transmit FIFO is disabled:

- 0 = No interrupt is generated.
- 1 = An interrupt is generated when the TDE flag (in the SCSR) is set. One value can be written to the STX Register when this interrupt occurs.

If the transmit FIFO is enabled:

- 0 = No interrupt is generated.
- 1 = An interrupt is generated when the TFE flag (in the SCSR) is set. When this interrupt occurs, up to eight values can be written to the STX, depending on the level of the TXFIFO watermark.

The TDE bit always indicates the STX Register empty condition, even when the transmitter is disabled by the transmit enable (TE) bit in the SCR2. Writing data to the STX or STSR clears the TDE bit, thus clearing the interrupt. Two transmit data interrupts with separate interrupt vectors are available:

1. Transmit data with exception status
2. Transmit data without exceptions

Table 11-5 shows the conditions under which these interrupts are generated and lists the interrupt vectors.

Table 11-6. ISSI Transmit Data Interrupts[1]

Interrupt	TIE	Selection Control		TUE
		TFEN = 0	TFEN = 1	
Transmit Data with Exception Status	1	TDE = 1	TFE = 1	1
Transmit Data (without exception)	1	TDE = 1	TFE = 1	0

1. See **Table 11-23** for a complete list of interrupts.

11.7.9.3 Receive Enable (RE)—Bit 13

This control bit enables the receive portion of the ISSI.

- 0 = The receiver is disabled by inhibiting data transfer into the SRX. If data is being received when this bit is cleared, the rest of the word is not shifted in nor is it transferred to the SRX Register. If the RE bit is re-enabled during a time-slot before the second to last bit, then the word will be received.
- 1 = The receive portion of the ISSI is enabled and receive data will be processed starting with the next receive frame sync.

Note: This bit should be cleared when clearing SSIEN.

11.7.9.4 Transmit Enable (TE)—Bit 12

This control bit enables the transfer of the contents of the STX Register to the Transmit Shift Register (TXSR) and also enables the internal gated clock.

- 0 = The transmitter continues to send the data currently in the TXSR and then disables the transmitter. The serial output enable signal is disabled and any data present in the STX Register is not transmitted. In other words, data can be written to the STX Register with the TE bit cleared, and the TDE bit is cleared but data is not transferred to the TXSR.
- 1 = On the next frame boundary, the transmit portion of the ISSI is enabled. With internally generated clocks, the frame boundary will occur within a word time. If the TE bit is cleared and set again during the same transmitted word, the data continues to be transmitted. If the TE bit is set again during a different time-slot, data is not transmitted until the next frame boundary.

The normal transmit enable sequence is to write data to the STX Register or to the STSR before setting the TE bit. The normal transmit disable sequence is to clear the TE bit and the TIE bit after the TDE bit is set.

When an internal gated clock is being used, the gated clock runs during valid time-slots if the TE bit is set. If the TE bit is cleared, the transmitter continues to send the data currently in the TXSR until it is empty. Then the clock stops. When the TE bit is set again, the gated clock starts immediately and runs during any valid time-slots.

Note: This bit should be cleared when clearing SSIEN.

11.7.9.5 Receive FIFO Enable (RFEN)—Bit 11

This control bit enables the FIFO Register for the receive section.

- 0 = Disables receive FIFO.
- 1 = Allows eight samples (depending on the receive watermark set in the SFCSR) to be received by the ISSI (a ninth sample can be shifting in) before the RFF bit is set and an interrupt request generated when enabled by the RIE bit.

11.7.9.6 Transmit FIFO Enable (TFEN)—Bit 10

This control bit enables the FIFO Register for the transmit section.

- 0 = Disables transmit FIFO.
- 1 = A maximum of eight samples can be written to the STX (a ninth sample can be shifting out).

11.7.9.7 Receive Clock Direction (RXDIR)—Bit 9

This control bit selects the direction and source of the clock signal used to clock the Receive Shift Register (RXSR).

- 0 = The internal clock generator is disconnected from the SRCK pin and an external clock source can drive this pin to clock the RXSR.
- 1 = The clock is generated internally and output to the SRCK pin.

Table 11-7 provides clock pin configuration options.

Note: RXDIR and SYN must both be high for the ISSI to be in Gated Clock mode.

Table 11-7. Clock Pin Configuration

SYN	RXDIR	TXDIR	RFDIR	TFDIR	SRFS	STFS	SRCK	STCK
Asynchronous Mode								
0	0	0	0	0	RFS In	TFS In	RCK In	TCK In
0	0	1	0	1	RFS In	TFS Out	RCK In	TCK Out
0	1	0	1	0	RFS Out	TFS In	RCK Out	TCK In
0	1	1	1	1	RFS Out	TFS Out	RCK Out	TCK Out
Synchronous Mode								
1	0	0	x	0	GPIO	FS In	GPIO	CK In
1	0	1	x	1	GPIO	FS Out	GPIO	CK Out
1	1	0	x	x	GPIO	GPIO	GPIO	Gated In
1	1	1	0	x	GPIO	GPIO	GPIO	Gated Out

11.7.9.8 Transmit Clock Direction (TXDIR)—Bit 8

This control bit selects the direction and source of the clock used to clock the TXSR.

- 0 = The internal clock generator is disconnected from the STFS pin and an external clock source can drive this pin to clock the TXSR.
- 1 = The clock is generated internally and is output to the STFS pin.

Table 11-7 illustrates the clock configuration options.

11.7.9.9 Synchronous Mode (SYN)—Bit 7

This control bit enables the Synchronous mode of operation. In this mode, the transmit and receive sections share a common clock pin and frame sync pin.

SYN and RXDIR control Gated Clock mode. The ISSI is in Gated Clock mode when both SYN and RXDIR are high.

Table 11-7 illustrates the clock configuration options.

- 0 = Other mode
- 1 = Synchronous mode

11.7.9.10 Transmit Shift Direction (TSHFD)—Bit 6

This bit controls whether the MSB or LSB is transmitted first for the transmit section.

- 0 = MSB data is transmitted first.
- 1 = LSB data is transmitted first.

Note: The codec device labels the MSB as bit zero, whereas the ISSI labels the LSB as bit zero. Therefore, when using a standard codec, the ISSI MSB (or codec bit 0) is shifted out first, and the TSHFD bit should be cleared.

11.7.9.11 Transmit Clock Polarity (TSCKP)—Bit 5

This control bit determines which bit clock edge is used to clock out data in the transmit section.

- 0 = The data is clocked out on the rising edge of the bit clock.
- 1 = The falling edge of the bit clock is used to clock out the data.

11.7.9.12 ISSI Enable (ISSIEN)—Bit 4

This control bit enables and disables the ISSI.

- 0 = The ISSI is disabled and held in a reset condition. When disabled, all output pins are tri-stated, the Status Register bits are preset to the same state produced by the Power-On Reset, and the Control register bits are unaffected. The contents of the STX, TXFIFO and RXFIFO are cleared when this bit is reset. When ISSI is disabled, all internal clocks are disabled except clocks required for register access. When clearing SSIEN, it is recommended to also clear RE and TE.
- 1 = The ISSI is enabled, causing an output frame sync to be generated when set up for internal frame sync or causes the ISSI to wait for the input frame sync when set up for external frame sync.

11.7.9.13 Network Mode (NET)—Bit 3

This control bit selects the Operational mode of the ISSI.

- 0 = Normal mode is selected.
- 1 = Network mode is selected.

11.7.9.14 Transmit Frame Sync Invert (TFSI)—Bit 2

This control bit selects the logic of frame sync I/O.

- 0 = The frame sync is active high.
- 1 = The frame sync is active low.

11.7.9.15 Transmit Frame Sync Length (TFSL)—Bit 1

This control bit selects the length of the frame sync signal to be generated or recognized. Please see **Figure 11-14** for an example timing diagram of the FS options.

- 0 = A one word-long frame sync is selected. The length of this word-long frame sync is the same as the length of the data word selected by WL.
- 1 = A one clock bit-long frame sync is selected.

The frame sync is deasserted after one bit for bit length frame sync and after one word for word length frame sync.

11.7.9.16 Transmit Early Frame Sync (TEFS)—Bit 0

This bit controls when the frame sync is initiated for the transmit and receive sections. See **Figure 11-14** for an example timing diagram of the FS options.

- 0 = The frame sync is initiated as the first bit of data is transmitted.
- 1 = The frame sync is initiated one bit before the data is transmitted. The frame sync is disabled after one bit-for-bit length frame sync and after one word-for-word length frame sync.

11.7.10 ISSI Time-Slot Register (STSR)

The STSR is used when data is not to be transmitted in an available transmit time-slot. For the purposes of timing, the Time-Slot Register is a *write-only* register. The register behaves like an alternate Transmit Data Register, except instead of transmitting data, the STFS signal is tri-stated. Using this register is important for avoiding overflow/underflow during inactive time-slots.

Base + $6	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read																
Write	DUMMY REGISTER, WRITTEN DURING INACTIVE TIME-SLOTS (NETWORK MODE)															
Reset	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Figure 11-16. ISSI Time-Slot Register (STSR)

See Programmer's Sheet on Appendix page B - 61

11.7.11 ISSI FIFO Control/Status Register (SFCSR)

This register provides for configuration of the transmit and receive FIFO Registers and allows for reporting of the amount of data contained in each FIFO.

Base + $7	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	RFCNT				TFCNT				RFWM				TFWM			
Write																
Reset	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Figure 11-17. ISSI FIFO Control/Status Register (SFCSR)

See Programmer's Sheet on Appendix page B - 62

11.7.11.1 Receive FIFO Counter (RFCNT)—Bits 15–12

This *read-only* bit field indicates the number of data words in the RXFIFO. **Table 11-8** provides the RFCNT bit field encoding.

Table 11-8. RFCNT[3:0] Encoding

Bits	Description
0000	0 data words in RXFIFO
0001	1 data word in RXFIFO
0010	2 data words in RXFIFO
0011	3 data words in RXFIFO
0100	4 data words in RXFIFO
0101	5 data words in RXFIFO
0110	6 data words in RXFIFO
0111	7 data words in RXFIFO
1000	8 data words in RXFIFO

11.7.11.2 Transmit FIFO Counter (TFCNT)—Bits 11–8

This *read-only* bit field indicates the number of data words in the TXFIFO. **Table 11-8** exhibits the TFCNT bit field encoding.

Table 11-9. TFCNT[3:0] Encoding

Bits	Description
0000	0 data words in TXFIFO
0001	1 data word in TXFIFO
0010	2 data words in TXFIFO
0011	3 data words in TXFIFO
0100	4 data words in TXFIFO
0101	5 data words in TXFIFO
0110	6 data words in TXFIFO
0111	7 data words in TXFIFO
1000	8 data words in TXFIFO

11.7.11.3 Receive FIFO Full WaterMark (RFWM)—Bits 7–4

This bit field controls the threshold where the Receive FIFO Full (RFF) flag will be set. RFF is set whenever the data level in the RXFIFO reaches the selected threshold. For example, if RFWM = 1, RFF will be set after the SSI received two data words (one in SRX and the other in RXFIFO). **Table 11-10** provides RFWM bit field encoding. **Table 11-11** shows the status of RFF for all data levels of the RXFIFO.

Table 11-10. RFWM Encoding

Bits	Description
0000	Reserved
0001	RFF set when at least one data word has been written to the RXFIFO. Set when RXFIFO = 1, 2, 3, 4, 5, 6, 7, or 8 data words
0010	RFF set when 2 or more data words have been written to the RXFIFO. Set when RXFIFO = 2, 3, 4, 5, 6, 7, or 8 data words
0011	RFF set when 3 or more data words have been written to the RXFIFO. Set when RXFIFO = 3, 4, 5, 6, 7, or 8 data words
0100	RFF set when 4 or more data words have been written to the RXFIFO. Set when RXFIFO = 4, 5, 6, 7, or 8 data words
0101	RFF set when 5 or more data words have been written to the RXFIFO. Set when RXFIFO = 5, 6, 7, or 8 data words
0110	RFF set when 6 or more data words have been written to the RXFIFO. Set when RXFIFO = 6, 7, or 8 data words
0111	RFF set when 7 or more data words have been written to the RXFIFO. Set when RXFIFO = 7 or 8 data words
1000	RFF set when 8 data words have been written to the RXFIFO. Set when RXFIFO = 8 data words

Table 11-11. Status of Receive FIFO Full Flag

Receive FIFO Watermark (RFWM)	Number of Data in RXFIFO								
	0	1	2	3	4	5	6	7	8
1	0	1	1	1	1	1	1	1	1
2	0	0	1	1	1	1	1	1	1
3	0	0	0	1	1	1	1	1	1
4	0	0	0	0	1	1	1	1	1
5	0	0	0	0	0	1	1	1	1
6	0	0	0	0	0	0	1	1	1
7	0	0	0	0	0	0	0	1	1
8	0	0	0	0	0	0	0	0	1

11.7.11.4 Transmit FIFO Empty WaterMark (TFWM)—Bits 3-0

This bit field controls the threshold where the Transmit FIFO Empty (TFE) flag is set. TFE is set whenever the data level in the TXFIFO falls below the selected threshold. **Table 11-12** provides TFWM bit field encoding. **Table 11-13** shows the status of TFE for all data levels of the TXFIFO.

Table 11-12. TFWM Encoding

Bits	Description
0000	Reserved
0001	TFE set when there is 1 empty slot in TXFIFO. (default) Transmit FIFO empty is set when TXFIFO <= 7 data.
0010	TFE set when there are 2 or more empty slots in TXFIFO. Transmit FIFO empty is set when TXFIFO <= 6 data.
0011	TFE set when there are 3 or more empty slots in TXFIFO. Transmit FIFO empty is set when TXFIFO <= 5 data.
0100	TFE set when there are 4 or more empty slots in TXFIFO. Transmit FIFO empty is set when TXFIFO <= 4 data.
0101	TFE set when there are 5 or more empty slots in TXFIFO. Transmit FIFO empty is set when TXFIFO <= 3 data.
0110	TFE set when there are 6 or more empty slots in TXFIFO. Transmit FIFO empty is set when TXFIFO <= 2 data.
0111	TFE set when there are 7 or more empty slots in TXFIFO. Transmit FIFO empty is set when TXFIFO = 1 data.
1000	TFE set when there are 8 empty slots in TXFIFO. Transmit FIFO empty is set when TXFIFO = 0 data.

Table 11-13. Status of Transmit FIFO Empty Flag

Transmit FIFO Watermark (TFWM)	Number of Data in TXFIFO								
	0	1	2	3	4	5	6	7	8
1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	0	0
3	1	1	1	1	1	1	0	0	0
4	1	1	1	1	1	0	0	0	0
5	1	1	1	1	0	0	0	0	0
6	1	1	1	0	0	0	0	0	0
7	1	1	0	0	0	0	0	0	0
8	1	0	0	0	0	0	0	0	0

11.7.12 ISSI Option Register (SOR)

Base + $9	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	0	0	RFDIR	TFDIR	0	0	0	0
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 11-18. ISSI Option Register (SOR)

See Programmer's Sheet on Appendix page B - 64

11.7.12.1 Reserved—Bits 15–6

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

11.7.12.2 Receive Frame Direction (RFDIR)—Bit 5

This control bit selects the direction and source of the Receive Frame Sync signal.

- 0 = The Receive Frame Sync is external, meaning the receive frame sync is supplied from an external source.
- 1 = The Receive Frame Sync is generated internally and output to the SRFS pin.

11.7.12.3 Transmit Frame Direction (TFDIR)—Bit 4

This control bit selects the direction and source of the Transmit Frame Sync signal.

- 0 = The Transmit Frame Sync is external, meaning the Receive Frame Sync is supplied form an external source.
- 1 = The Transmit Frame Sync is generated internally and output to the STFS pin.

The ISSI has two basic operating modes. **Table 11-14** lists those operating modes and some of the typical applications when they can be used. These distinctions result in the basic operating modes, allowing the ISSI to communicate with a wide variety of devices. These modes can be programmed by several bits in the ISSI Control Registers. Please see **Table 11-8.**

11.7.12.4 Reserved—Bits 3–0

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

11.8 ISSI Operating Modes

The ISSI supports both Normal and Network modes. Either can be selected independently of whether the transmitter and receiver are synchronous or asynchronous. Typically, these protocols are used in a periodic manner where data is transferred at regular intervals, such as at the sampling rate of an external codec. Both modes use the concept of a frame. The beginning of the frame is marked with a frame sync when programmed with continuous clock. The frame sync occurs at a periodic interval. The length of the frame is determined by the DC and WL bits in either the SRXCR or STXCR, depending on whether data is being transmitted or received.

Table 11-14. ISSI Operating Modes

TX, RX Sections[1]	Serial Clock[2]	Mode[3]	Typical Application
Asynchronous	Continuous	Normal	Multiple synchronous codecs
Asynchronous	Continuous	Network	TDM codec or Controller networks
Synchronous	Continuous	Normal	Multiple synchronous codecs
Synchronous	Continuous	Network	TDM codec or Controller network
Synchronous	Gated[4]	Normal	SPI-type devices; Controller to MCU

1. In the Synchronous mode, the transmitter and receiver use a common clock and frame synchronization signal. In the Asynchronous mode, the transmitter and receiver operate independently, on their own clocks and frame syncs.
2. In Continuous mode the clocks run all the time. In the Gated Clock mode the clock operates only when there is data to exchange.

3. In the Normal mode, the SSI only transmits during the first time-slot of each I/O frame. In the Network mode, any number from 1 to 32 data words of I/O per frame can be used. The Network mode is typically used in star or ring time division multiplex networks with other processors or codecs, allowing interface to TDM networks without additional logic.
4. Use of gated clock is not allowed in the Network mode.

11.8.1 Normal Mode

The Normal mode is the simplest mode of the ISSI. It is used to transfer one word per frame. In the Continuous Clock mode, a frame sync occurs at the beginning of each frame. The length of the frame is determined by the following factors:

- The period of the serial bit clock (PSR, PM bits for internal clock or the frequency of the external clock on the STCK or SRCK pins)
- The number of bits per sample (WL bits)
- The number of time-slots per frame (DC bits)

If the Normal mode is configured to provide more than one time-slot per frame, data is transmitted only in the first time-slot. No data is transmitted in subsequent time-slots. **Figure 11-19** and **Figure 11-20** provide sample timing of the Normal mode transfers.

11.8.1.1 Normal Mode Transmit

The conditions for data transmission from the ISSI in the Normal mode are as follows:

1. Set the SCSR, STXCR, SCR2, and SOR to select the Normal mode operation, define the transmit clock, transmit frame sync and frame structure required for proper system operation.
2. ISSI Enabled (ISSIEN = 1)
3. Enable TXFIFO (TFEN=1) and configure the transmit watermark (TFWM = n) if this TXFIFO is used.
4. Write data to Transmit Data (STX) Register.
5. Enable transmit interrupts.
6. Set the TE bit (TE = 1) to enable the transmitter on the next frame sync boundary.

Figure 11-25 and **Table 11-15** describe the functions performed during transmit operation in this mode.

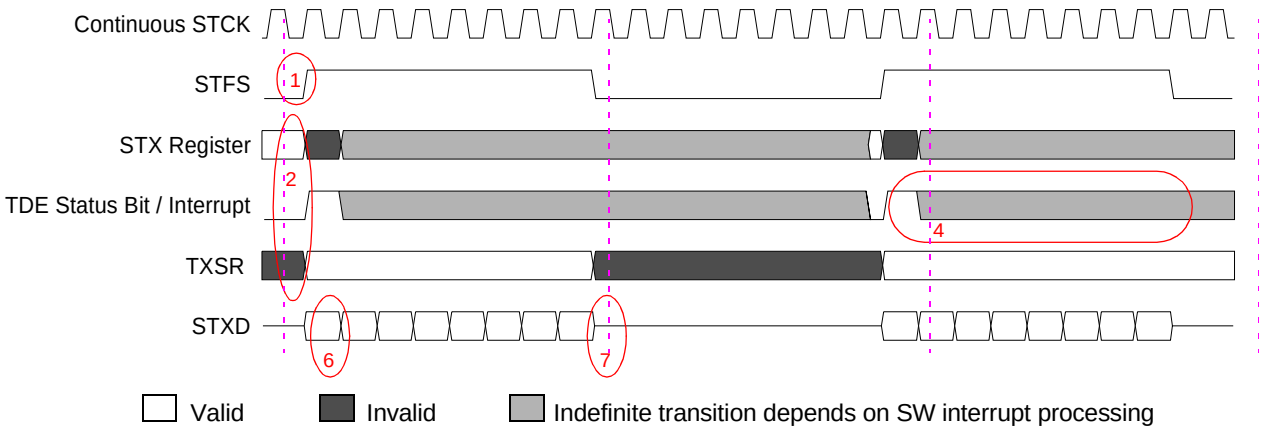


Figure 11-19. Normal Mode Transmit Timing—Continuous Clock (WL=8 bit words, DC=1)

Table 11-15. Normal Mode Transmit Operations

Step		TXFIFO Disabled (See Figure 11-24)	TXFIFO Enabled (No Figure Available)
1	Rising edge of STFS. Note that a word length frame sync is shown. This only works if DC>0.	—	—
2	Data transferred to TXSR	From STX	From TXFIFO
3	STXD output pin is enabled[1] and the first bit of the TXSR appears on the output	—	—
4	Flag status update	The TDE bit is set	The TFE bit is set if the level of data in the TXFIFO falls below the watermark level.
5	If the TIE bit is set, enabling transmit interrupts, then: (Other options for processing the data transfer is either polling or DMA transfers.)	Transmit interrupt occurs when TDE set.	Transmit interrupt occurs when TFE set.
6	The TXSR is shifted on the next rising edge of STCK and the next bit appears on the STXD pin.	—	—
7	When WL bits (see Section 11.7.7) have been sent the STXD is tri-stated.	—	—
8	Transmit under-run (setting the TUE bit of the SCSR) is prevented by[2]:	New data is written to the STX before the TXSR tries to obtain new transmit data at the next frame sync.	New data is written to the STX before the TXSR tries to obtain data from an empty TXFIFO (this can be several frame times).
9	Repeat at step 1 on the next frame sync.[3]	—	—

1. The STXD output signal is disabled except during the data transmission period.
2. See the description of the TUE bit in Section 11.7.8 for a description of what happens when the TUE bit is set.
3. The frame sync must not occur earlier than what is configured in the STXCR as documented in Section 11.7.7.

11.8.1.2 Normal Mode Receive

The conditions for data reception from the ISSI are as follows:

1. Set the SCSR, SRXCR, SCR2, and SOR to select the Normal mode operation, define the receive clock, receive frame sync and frame structure required for proper system operation.
2. ISSI Enabled (ISSIEN = 1)
3. Enable RXFIFO (RFEN=1) and configure Receive WaterMark (RFWM = n) if RXFIFO is used.
4. Enable receive interrupts
5. Set the RE bit (RE = 1) to enable the receiver operation on the next frame sync boundary.

Figure 11-20 and **Table 11-16** describes the functions performed during receive operation in this mode.

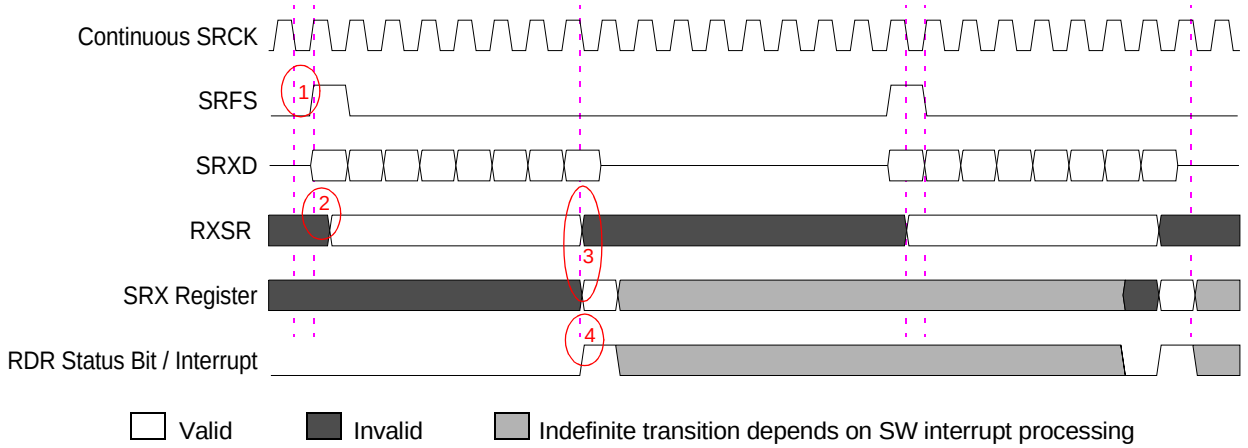


Figure 11-20. Normal Mode Receive Timing—Continuous Clock (WL=8 bit words, DC=1)

Table 11-16. Normal Mode Receive Operations

Step		RXFIFO Disabled (See Figure 11-20)	RXFIFO Enabled (No Figure Available)
1	Leading edge of frame sync occurs on the SRFS pin	—	—
2	Falling edge of receive clock occurs on the SRCK pin and the next bit of data is shifted into the RXSR	—	—
3	When WL bits (see Section 11.7.7) have been received RXSR contents are transferred to the SRX Register on the next falling edge of the receive clock. Note that the SRX Register is actually loaded during the middle of the last receive bit.	—	—
4	Flag status update	The RDR bit is set	The RFF bit is set if the level of data in the RXFIFO rises above the watermark level.
5	If the RIE bit is set, enabling receive interrupts, then: (Other options for processing the data transfer is either polling or DMA transfers.)	Receive interrupt occurs when RDR set.	Receive interrupt occurs when RFF set.
6	Receive over-run (setting the ROE bit of the SCSR) is prevented by[1]:	Data is read from the SRX before the RXSR tries to write new transmit data at the next frame sync.	Data is read from the SRX before the RXSR tries to provide more data to a full RXFIFO (it can take several frame times to fill the RXFIFO).
7	Repeat at step 1 on the next frame sync.[2]	—	—

1. See the description of the ROE bit in Section 11.7.8 for a description of what happens when the ROE bit is set.
2. The frame sync must not occur earlier than what is configured in the SRXCR as documented in Section 11.7.7.

11.8.1.3 Gated Clock Operation

Gated Clock mode is often used to hook-up to SPI-type interfaces on microcontroller units (MCU's) or external peripheral chips. In the Gated Clock mode, the presence of the clock indicates valid data is on the STXD or SRXD pins. For this reason, no frame sync is required in this mode. Once transmission of data has completed, the clock is stopped.

Because the Gated Clock mode is a synchronous mode, only the STCK is used. Please see **Table 11-13.** This clock can be generated internally using the Master mode, or externally, using the Slave mode. Several operating modes are possible as detailed in **Table 11-17.**

Table 11-17. Transmit and Receive Enables in Gated Clock Mode

Enables		Possible Clock Source	Operating Mode
TE	RE		
0	0	—	Not operational
0	1	External	Receive only -- receiver gets data when clocks occur
1	0	Internal or External	Transmit only -- data transfer as clocks occur
1	1	Internal or External	Transmit and receive operate synchronously -- data is transferred as clocks occur.

For the case of internally generated clock, all internal bit clocks, word clocks, and frame clocks continue to operate (although the frame clock is ignored). When data is written to the STX Register, the clock will operate starting when the next word clock (time-slot) occurs. This allows data to be transferred out in periodic intervals in the Gated Clock mode.

With an external clock, the ISSI waits for a clock signal to be received. Once the clock begins, valid data is shifted in/out.

Note: The bit clock pins must be kept free of timing glitches. If a single glitch occurs, all ensuing transfers will be out of synchronization.

Figure 11-26 shows a gated clock timing diagram with comments in **Table 11-18.**

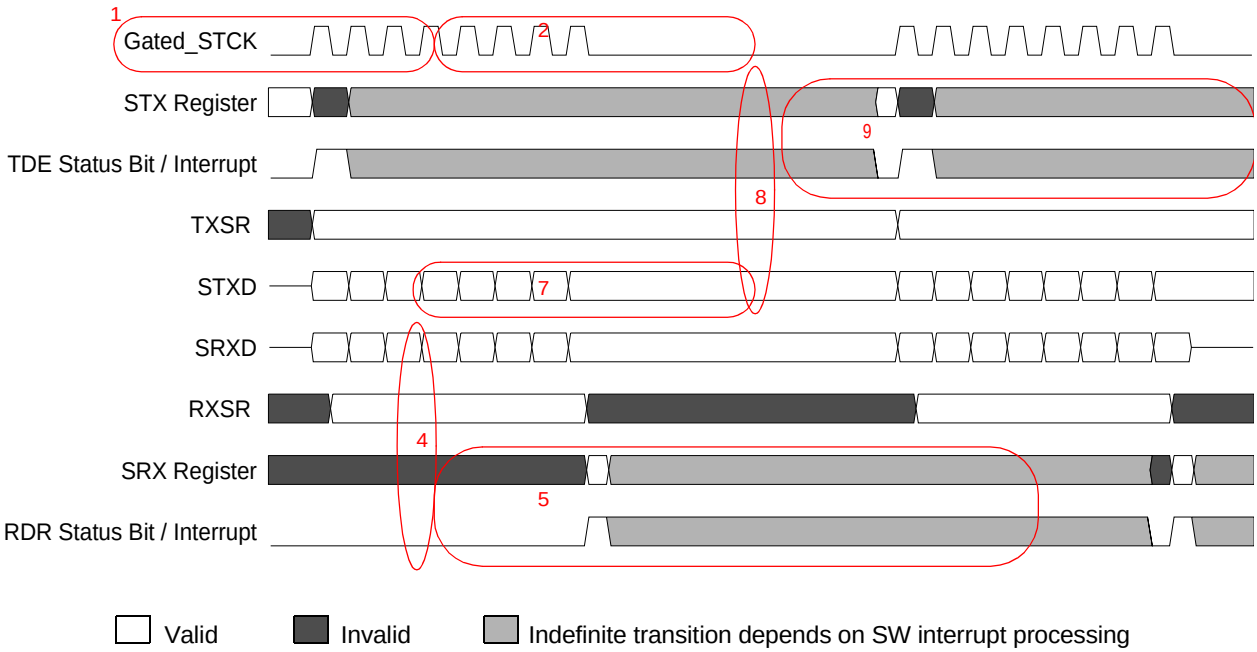


Figure 11-21. Normal Mode Timing—Gated Clock

Table 11-18. Gated Clock Operations

Step		FIFOs Disabled (See Figure 11-26)	FIFOs Enabled (No Figure Available)
1	Clocks occur on STCK to clock data out on the STXD pin and in on the SRXD pin.	—	—
2	Clocks stop on STCK and no data is transferred. Note that the idle time is a multiple of word times, when the clock is generated internally.	—	—
3	All other timing of transmit and receive functions continue as in the Normal mode.	—	—
4	Receive flag status update. The last bit of the receive data is captured on the last falling clock edge before the clock is gated off. The receive interrupt does not occur at the same time as the transmit interrupt, if both are enabled.	The RDR bit is set	The RFF bit is set if the level of data in the RXFIFO rises above the watermark level.
5	If the RIE bit is set, enabling receive interrupts, then: (Other options for processing the data is either polling or DMA transfers.)	Receive interrupt occurs when RDR set.	Receive interrupt occurs when RFF set.
6	Receive over-run (setting the ROE bit of the SCSR) is prevented by[1]:	Data is read from the SRX before the RXSR tries to write new transmit data at the next frame sync.	Data is read from the SRX before the RXSR tries to provide more data to a full RXFIFO (it can take several frame times to fill the RXFIFO).
7	At the end of the transmit word, the STXD pin continues to drive. In the general case where STCK is driven externally, the transmitter does not know when the normal end of the list bit time is.	—	—
8	Transmit status flag update	TDE bit is set	The TFE bit is set if the level of data in the TXFIFO falls below the watermark level.
9	If the TIE bit is set, enabling transmit interrupts, then: (Other options for processing the data is either polling or DMA transfers.)	Transmit interrupt occurs when TDE set.	Transmit interrupt occurs when TFE set.
	Repeat at step 1 on the next frame sync.[2]	—	—

1. See the description of the ROE bit in **Section 11.7.8** for a description of what happens when the ROE bit is set.
2. The frame sync must not occur earlier than what is configured in the SRXCR as documented in **Section 11.7.7.**

11.8.2 Network Mode

The Network mode is used for creating a Time Division Multiplexed (TDM) network, such as a TDM codec network or a network of Controllers. This mode only operates with the Continuous Clock mode. A frame sync occurs at the beginning of each frame. In this mode, the frame is divided into more than one time-slot. During each time-slot, one data word can be transferred. Each time-slot is then assigned to an appropriate codec or Controller on the network. The Controller can be a master device controlling its own private network, or a slave device connected to an existing TDM network and occupies a few time-slots.

The frame sync signal indicates the beginning of a new data frame. Each data frame is divided into time-slots and transmission and/or reception of one data word can occur in each time-slot (rather than in just the frame sync time-slot as in the Normal mode). The frame rate dividers, controlled by the DC bits, select two to thirty-two time-slots per frame. The length of the frame is determined by the following factors:

- The period of the serial bit clock (PSR, PM bits for internal clock, or the frequency of the external clock on the STCK and/or SRCK pins)
- The number of bits per sample (WL bits)
- The number of time-slots per frame (DC bits)

While in the Network mode, data can be transmitted in any time-slot. The distinction of the Network mode is that each time a slot is identified with respect to the frame sync (data word time). This time-slot identification allows the option of transmitting data during the time-slot by writing to the STX Register, or ignoring the time-slot by writing to STSR. The receiver is treated in the same manner, except data is always being shifted into the RXSR and transferred to the SRX Register. The core reads the SRX Register and either uses it or discards it.

Figure 11-27 and **Figure 11-23** show sample timing of Network mode transfers. The figures illustrate receive and transmit frames of five time-slots for each. The numbered circles and arrows in the figure identify discussion notes contained in **Table 11-19** and **Table 11-20.**

11.8.2.1 Network Mode Transmit

The transmit portion of the ISSI is enabled when the ISSIEN and the TE bits in the SCR2 are both set. However, when the TE bit is set, the transmitter is enabled only after detection of a new frame boundary. Software must find the start of the next frame by checking the TFS bit of the SCSR. A normal start-up sequence for transmission is:

1. Set the SCSR, STXCR, SCR2 and SOR to select the Network mode operation, define the transmit clock, transmit frame sync and frame structure required for proper system operation.
2. ISSI Enabled (ISSIEN = 1)
3. Enable TXFIFO (TFEN=1) and configure the Transmit WaterMark (TFWM = n) if this TXFIFO is used.
4. Write data to Transmit Data (STX) Register
5. Enable transmit interrupts.
6. Set the TE bit (TE = 1) to enable the transmitter on the next frame sync boundary.

The transmitter timing for an 8-bit word with continuous clock, FIFO disabled, five words per frame sync, in the Network mode shown in **Figure 11-26.** The explanatory notes for the transmit portion of the figure are shown in **Table 11-19.**

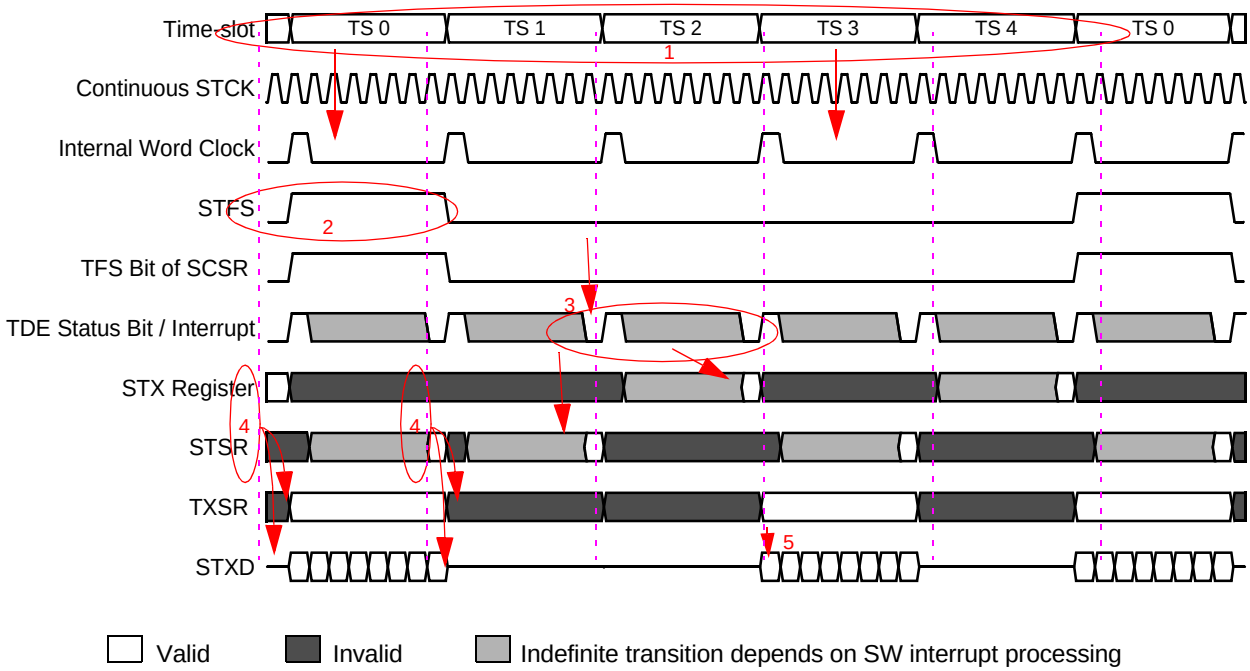


Figure 11-22. Network Mode Transmit Timing

Table 11-19. Notes for Transmit Timing in Figure 11-22

Note	Source Signal	Destination Signal	Description
1	—	—	Example of a five time-slot frame, transmitting in time-slots 0 and 3.
2	STFS	—	Example with word-length frame sync and standard timing (TFSI=0, TFSL=0, and TEFS=0). Frame timing begins with the rising edge of SC2.
3	—	TDE Status Flag and Interrupt	This flag is set at the beginning of each word to indicate another data word should be supplied by the software. When the transmit interrupt is enabled, the processor is interrupted to request the data. The flag and interrupt are cleared when data is written to either the STX or STSR.[1]
4	STX / STSR	TXSR	On each word clock boundary a decision is made concerning what to transmit on the next time-slot. If the STSR was written during the previous time-slot the STXD pin is tri-stated. If the STSR was NOT written during the previous time-slot the contents of the STX Register is transferred to the TXSR and this data is shifted out. If the STX Register has not been written in the previous time-slot the previous data is reused. If neither of these registers were written in the previous time-slot the TUE status bit will be set and the hardware will operate as if the STX Register had been written. The STXD pin will be enabled and the contents of the STX will be transmitted again. This may lead to drive conflicts on the transmit data line.
5	TXSR	STXD Pin	On active time-slots, the TXSR contents are shifted out on the STXD pin, one bit per rising edge of SCK. On inactive time-slots, the STXD pin is tri-stated so it can be driven by another device.

1. **Section 11.12.1** provides a complete description of interrupt processing.

The operation of clearing the TE bit disables the transmitter after completion of transmission of the current data word. Setting the TE bit again enables transmission of the next word. During the time TE = 0, the STXD signal is tri-stated. The TE bit should be cleared after the TDE bit is set, ensuring all pending data is transmitted.

In summary, the Network mode transmitter generates interrupts every time-slot, requiring the Controller program to respond to each time-slot. These responses may be one of the following:

- Write the Data Register with data to enable transmission in the next time-slot.
- Write the Time-Slot Register to disable transmission in the next time-slot.
- Do nothing—transmit underrun occurs at the beginning of the next time-slot and the previous data is re-transmitted.

11.8.2.2 Network Mode Receive

The receiver portion of the ISSI is enabled when both the ISSIEN and the RE bits in the SCR2 are set. However, when the RE bit is set, the receiver is enabled only after detection of a new frame boundary. Software has to find the start of the next frame. Locating the start of the next frame is achieved by checking the RFS bit in the SCSR. A normal start-up sequence for receive operation is to do the following:

1. Set the SCSR, SRXCR, SCR2, and SOR to select the Network mode operation, define the receive clock, receive frame sync and frame structure required for proper system operation.
2. ISSI Enabled (ISSIEN = 1)
3. Enable RXFIFO (RFEN=1) and configure receive watermark (RFWM = n) if RXFIFO is used.
4. Enable receive interrupts.
5. Set the RE bit (RE = 1) to enable the receiver operation on the next frame sync boundary.

The receiver timing for an 8-bit word with continuous clock, FIFO disabled, five words per frame sync, in the Network mode is shown in **Figure 11-23.** The explanatory notes for the receive portion of the figure are shown in **Table 11-20.**

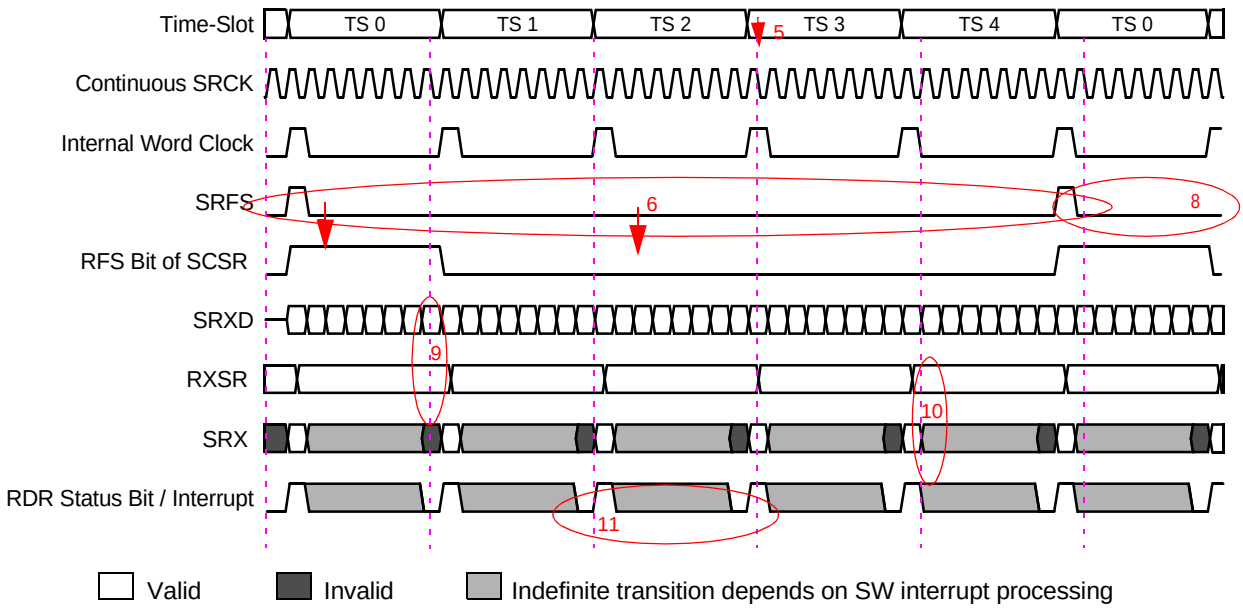


Figure 11-23. Network Mode Receive Timing

Table 11-20. Notes for Receive Timing in Figure 11-23

Note	Source Signal	Destination Signal	Description
6	—	—	Example of a 5 time-slot frame, receiving data from time-slots 0 and 2. Note that the receive hardware will obtain data on the pin every bit time. The software must determine which data belongs to each time-slot and discard the unwanted time-slot data.
7	STFS	—	The figure shows the transmit and receive timing as the same, although this is not the general case.
8	STFS	—	Example with bit-length frame sync and standard timing (RFSI=0, RFSL=1, REFS=0). Frame timing begins with the rising edge of STFS.
9	STFS	RXSR	Data on the STFS pin is sampled on the falling edge of STFS and shifted into the RXSR.
10	RXSR	SRX Register	At the word clock, the data in the RXSR is transferred to the SRX Register.
11	RDR Status Flag and Receive Interrupt	—	This flag is set for each word clock (time-slot) to indicate that data is available to be processed. The software must keep track of the time-slots as they occur so it knows which data to keep. If the receive interrupts are enabled (RIE=1) an interrupt will be generated when this status flag is set. The software reads the SRX Register to clear the interrupt (see **Section 11.12.1** for a complete description of interrupt processing).

An interrupt can occur after the reception of each data word or the programmer can poll the RDR flag. The ISSI program response can be one of the following:

- Read SRX and use data
- Read SRX and ignore data
- Do nothing–the receiver overrun exception occurs at the end of current time-slot

11.8.2.3 Synchronous/Asynchronous Operating Modes

The transmit and receive sections of the ISSI may be synchronous or asynchronous. During asynchronous operation the transmitter and receiver have their own separate clock and sync signals. When operating in Synchronous mode, the transmitter and receiver use common clock and synchronization signals, as specified by the transmitter configuration. The SYN bit in SCR2 selects synchronous or asynchronous operation.

Since the SSI is designed to operate either synchronously or asynchronously, separate receive and transmit interrupts are provided. During synchronous operation, the receiver and transmitter operate in lock step with each other. The software designer may want to reduce overhead by eliminating either the receive or transmit interrupts, driving both channels from the same set of interrupts. If this decision is made, the software designer needs to be aware of the specific timing of the receive and transmit interrupts since the interrupts are not generated at the same exact point in the frame timing, depicted in **Figure 11-14.** If it is desired to run off a single set of interrupts, the TX interrupts should be used. If RX interrupts are used, there may be timing problems with

the transmit data because this interrupt occurs a half-bit time before the transmit data is used by the hardware.

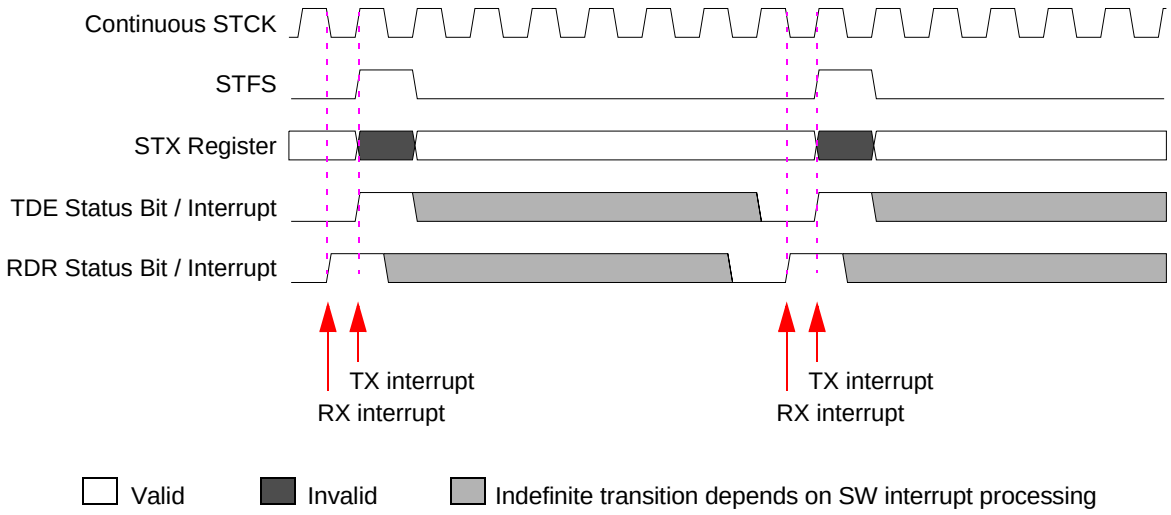


Figure 11-24. Synchronous Mode Interrupt Timing

11.9 Clocks

The ISSI uses the following three clocks, illustrated in **Figure 11-5** and **Figure 11-26**:

- Bit clock—Used to serially clock the data bits in and out of the ISSI port
- Word clock—Used to count the number of data bits per word (8, 10, 12, or 16 bits)
- Frame clock—Used to count the number of words in a frame

The bit clock is used to serially clock the data. It is visible on the Serial Transmit Clock (STCK) and Serial Receive Clock (SRCK) pins. The word clock is an internal clock used to determine when transmission of an 8, 10, 12, or 16 bit word has completed. The word clock in turn then clocks the frame clock, marking the beginning of each frame. The frame clock can be viewed on the Serial Transmit Frame Sync (STFS) and Serial Receive Frame Sync (SRFS) pins. The bit clock can be received from an ISSI clock pin or can be generated from the peripheral clock passed through a divider, as shown in **Figure 11-25**.

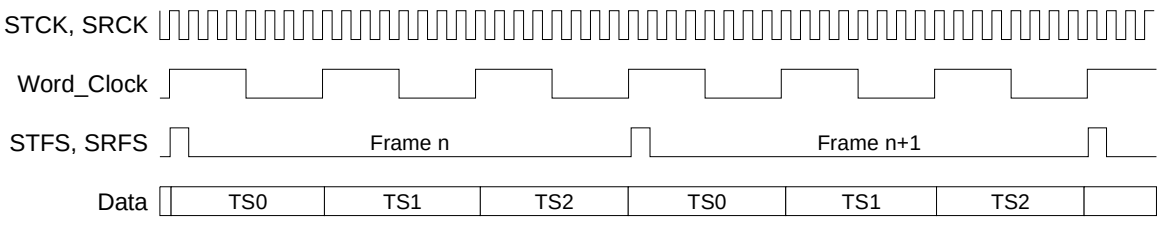


Figure 11-25. ISSI Clocking (8-bit words, 3 time-slots / frame)

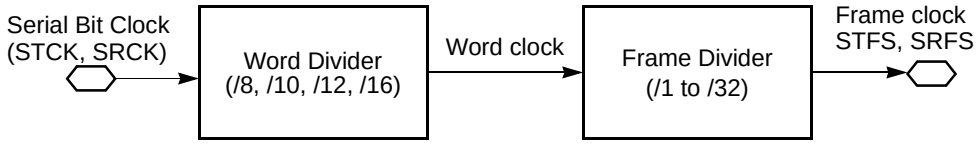


Figure 11-26. ISSI Clock Generation

Table 11-21. Clock Summary

Clock	Source	Characteristics
STCK	Internal / External	Transmit data is changed on the rising edge of this clock. The TSCKP bit of the SCR2 can invert the clock if required.
SRCK	Internal / External	Receive data is captured on the falling edge of this clock. The RSCKP bit of the SCSR can invert the clock if required.
SRFS	Internal / External	Receive frames begin with the rising edge of this signal. See the definition of the REFS bit of the SCSR for timing options.
STFS	Internal / External	Transmit frames begin with the rising edge of this signal. See the definition of the TEFS bit of the SCR2 for timing options. The TFSI bit can invert this signal if required.

11.10 Clock Operation Description

11.10.1 ISSI Clock and Frame Sync Generation

Data clock and frame sync signals can be generated internally by the ISSI or can be obtained from external sources. If internally generated, the ISSI clock generator is used to derive bit clock and frame sync signals from the peripheral clock. The ISSI clock generator consists of a selectable, fixed prescaler and a programmable prescaler for bit rate clock generation. In Gated Clock mode, the data clock is valid only when data is being transmitted. Please review **Section 11.8.1.3** for additional information about Gated Clock Operation. A programmable frame rate divider and a word length divider are used for frame rate sync signal generation.

Figure 11-27 shows a block diagram of the clock generator for the transmit section. The serial bit clock can be internal or external, depending on the Transmit Direction (TXDIR) bit in the ISSI Control Register 2 (SCR2). The receive section contains an equivalent clock generator circuit.

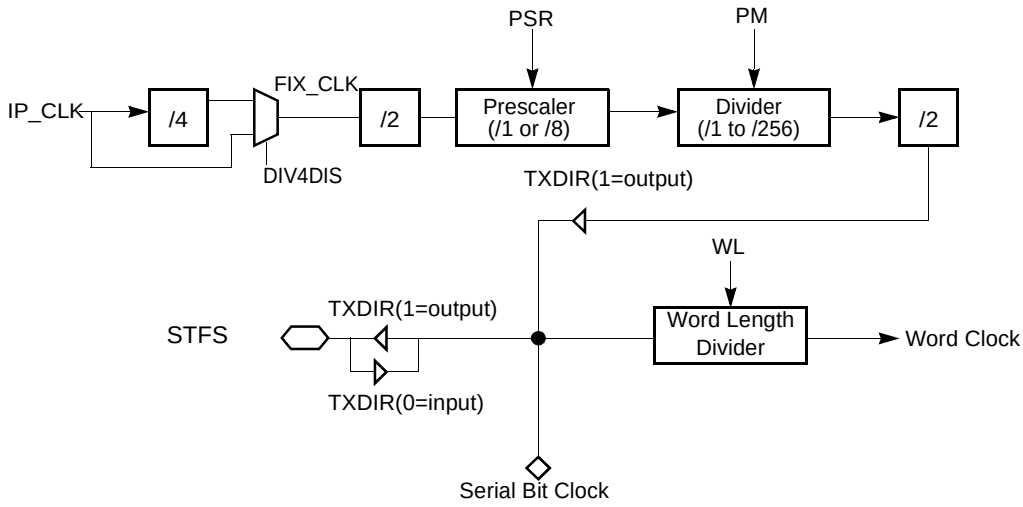


Figure 11-27. ISSI Transmit Clock Generator Block Diagram

Figure 11-28 illustrates the frame sync generator block for the transmit section. When internally generated, both receive and transmit frame sync are generated from the word clock and are defined by the frame rate divider (DC) bits and the word length (WL) bits of the ISSI Transmit Control Register (STXCR). The receive section contains an equivalent circuit for its frame sync generator.

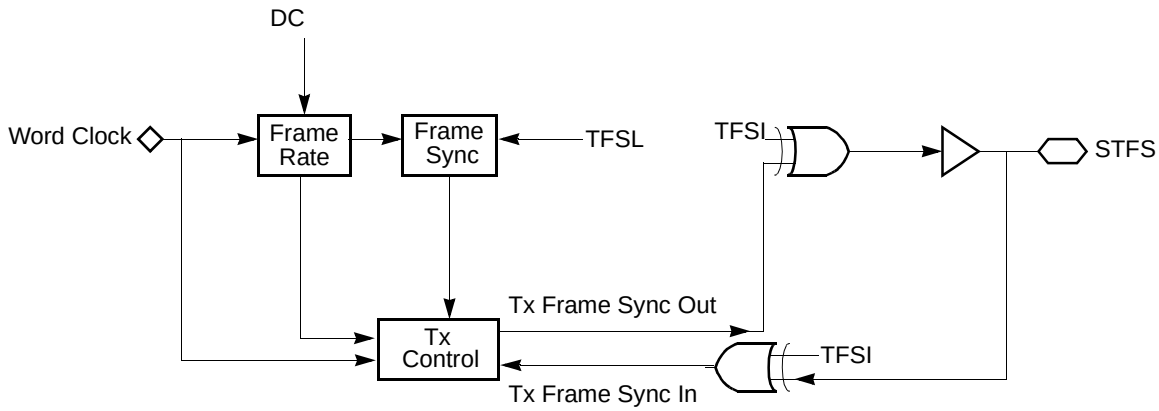


Figure 11-28. ISSI Transmit Frame Sync Generator Block Diagram

11.11 Resets

The ISSI is affected by Power-On Reset and ISSI reset.

Power-On Reset is generated by asserting either the RESET pin or the Computer Operating Properly (COP) timer reset. The Power-On Reset initializes all control registers. The reset also clears the ISSIEN bit in SCR2 and disables the ISSI.

The SSI reset is generated when the ISSIEN bit in the SCR2 is cleared. The ISSI status bits are preset to the same state produced by the Power-On Reset. The ISSI control bits are unaffected. The control bits in the top half of the SCSR are also unaffected. The ISSI reset is useful for selective reset of the ISSI without changing the present ISSI control bits and without affecting the other peripherals.

The correct sequence to initialize the ISSI is as follows:

1. Issue a power-on or ISSI reset.
2. Program the ISSI control registers.
3. Set the ISSIEN bit in SCR2.

To ensure proper operation of the ISSI, the programmer should use the power-on or ISSI reset before changing any of the following control bits listed in **Table 11-14.**

Note: These control bits should not be changed during ISSI operation.

Note: The ISSI bit clock must go low for at least one complete period to ensure proper ISSI reset.

Table 11-22. ISSI Control Bits Requiring Reset Before Change

Control Register	Bit
SRXCR STXCR	PSR WL DC PM
SCR2	TEFS TFSL TFSI NET TSCKP TSHFD SYN
SCSR	REFS RFSL RFSI RSCKP RSHFD DIV4DIS

11.12 Interrupts

The ISSI can generate up to six interrupt vectors, illustrated in **Table 11-23.** Some implementations of the SSI do not included the last slot interrupts; therefore, those implementations only generate four interrupts.

Table 11-23. Interrupt Summary

Interrupt	Source	Description
INTR+0	Receiver	Receive Data with Exception
INTR+2	Receiver	Receive Data
INTR+4	Receiver	Receive Last Slot Interrupt - this interrupt may not be present in all implementations of the ISSI.
INTR+6	Transmitter	Transmit Data with Exception
INTR+8	Transmitter	Transmit Data
INTR+10	Transmitter	Transmit Last Slot Interrupt - this interrupt may not be present in all implementations of the ISSI.

11.12.1 Interrupt Operation Description

11.12.1.1 Receive Data With Exception

This interrupt can occur when receive interrupts are enabled via the RIE bit of the SCR2. When a data word is ready to transfer from the RXSR to the SRX and the previous SRX data has not been read yet the ROE bit is set and the exception interrupt will occur instead of the normal receive data interrupt.

11.12.1.2 Receive Data

An interrupt can occur when receive interrupts are enabled via the RIE bit of the SCR2. When a data word is ready to transfer from the RXSR to the SRX, and the ROE bit is not set, this interrupt will occur indicating received data is available for processing. When the receive FIFO is enabled, this interrupt will not occur until the receive watermark level of the FIFO is reached. If the FIFO is not enabled this interrupt will occur for each data word received.

11.12.1.3 Transmit Data With Exception

This interrupt can occur when transmit interrupts are enabled via the TIE bit of the SCR2. When it is time to transfer data to the TXSR and no data is available in the STX or TXFIFO (if enabled) the TUE status bit is set and the transmit data exception interrupt occurs.

11.12.1.4 Transmit Data

This interrupt can occur when transmit interrupts are enabled via the TIE bit of the SCR2. When data is transferred to the TXSR, this interrupt will develop if more data is needed. If the transmit FIFO is not enabled, this interrupt will occur for each data word transmitted. When the transmit FIFO is enabled, the interrupt will not occur until the transmit watermark level is reached.

11.13 User Notes

11.13.1 External Frame Sync Setup

When using external frame syncs, there must be at least four clocks after enabling the transmitter/receiver and before the first frame sync.

11.13.2 Maximum External Clock Rate

The maximum allowable rate for an external clock source is one fourth of the peripheral clock.

Chapter 12
Quad Timer (TMR)

12.1 Introduction

The Quad Timer (TMR) module contains four identical counter/timer groups. Each 16-bit counter/timer group contains a

- Prescaler
- Counter
- Load register
- Hold register
- Capture register
- Two Compare registers
- Two Status and Control registers

All except the prescaler are read/write registers.

Note: This document uses the terms *Timer* and *Counter* interchangeably because the counter/timers may perform either or both tasks.

The Load Register provides the initialization value to the counter when the counter's terminal value has been reached. The Hold registers capture the counter's value the instant any counter register is read. This feature supports the reading of cascaded counters. The Capture Register enables an external signal to take a *snapshot* of the counter's current value. The TMR_CMP1 and TMR_CMP2 registers provide the values to which the counter is compared. If a match occurs, the OFLAG signal can be set, cleared, or toggled. At match time, an interrupt is generated if enabled. The Prescaler provides different IPBus Clock time bases useful for clocking the counter. The Counter provides the ability to count internal or external events. Input pins are shared within a Timer module.

12.2 Features

The Quad TMR module design includes these distinctive capabilities:

- Four, 16-bit counters/timers
- Count up/down
- Counters are cascadable
- Count modulo can be programmed
- Maximum count rate equals peripheral clock for external clocks
- Maximum count rate equals peripheral clock for internal clocks
- Count once or repeatedly

- Counters can be preloaded
- Counters can share available input pins
- Separate prescaler for each counter
- Each counter has capture and compare capability

12.3 Operating Modes

The TMR module design operates in only the Functional mode. Various counting modes are detailed in *Functional Description,* **Section 12.6**.

12.4 Block Diagram

The block diagram of the Quad TMR module is illustrated in **Figure 12-1.**

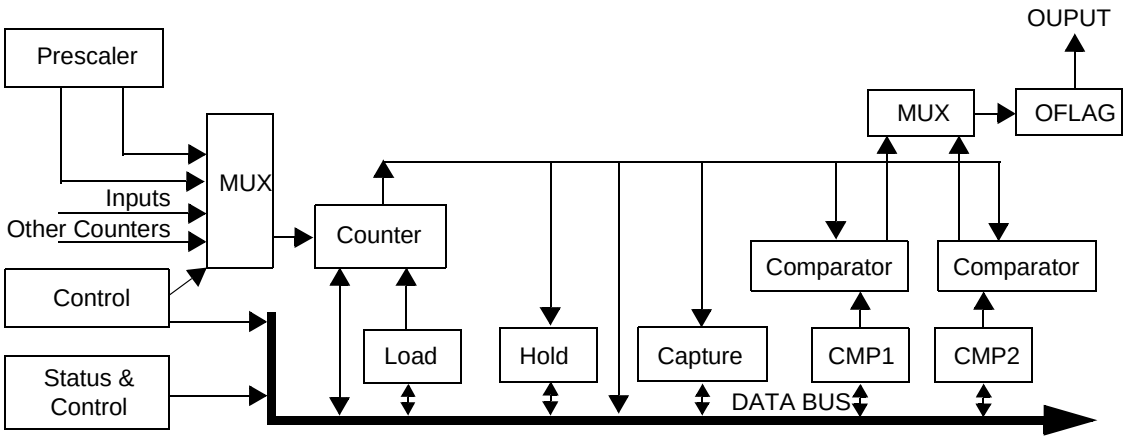


Figure 12-1. TMR Module Block Diagram

12.5 Signal Description

The TMR module has four external signals TIO[3:0] with the capability to be used as either inputs or outputs.

12.6 Functional Description

The counter/timer has two basic modes of operation:

1. Count internal or external events
2. Count an internal clock source while an external input signal is asserted, thus timing the width of the external input signal

The counter can count the rising, falling, or both edges of the selected input pin. The counter can decode and count quadrature encoded input signals. The counter can count up and down using dual inputs in a count with direction format. The counter's terminal count value (modulo) is programmable. The value loaded into the counter after reaching its terminal count is programmable. The counter can count repeatedly, or it can stop after completing one count cycle. The counter can be programmed to count to a programmed value and then immediately reinitialize, or it can count through the compare value until the count rolls over to zero.

The external inputs to each counter/timer can be shared among each of the four counter/timers within the module. The external inputs can be used as:

- Count commands
- Timer commands
- Trigger current counter value to be *captured*
- Generate interrupt requests

The polarity of the external inputs can be selected. For this implementation of the Timer (TMR), there are four input pins. The primary output of each timer/counter is the output signal, OFLAG. The OFLAG output signal can be set, cleared, or toggled when the counter reaches the programmed value. The OFLAG output signal may be output to an external pin shared with an external input signal (TIOx).

The OFLAG output signal enables each counter to generate square waves (PWM) or pulse stream outputs. The polarity of the OFLAG output signal is selectable.

Any counter/timer can be assigned as a Master (MSTR). A master's compare signal can be broadcasted to the other counter/timers within the module. The other counters can be configured to reinitialize their counters and/or force their OFLAG output signals to predetermined values when a Master's Counter/Timer compare event occurs.

12.7 Counting Modes Definitions

The selected external count signals are sampled at the TMR's base clock rate (60MHz) and then run through a transition detector. The maximum count rate is one-half of the base peripheral clock rate. Internal clock sources can be used to clock the counters at the peripheral clock rate.

If a counter is programmed to count to a specific value and then stop, the Count mode in the TMR_CTRL register is cleared when the count terminates.

12.7.1 Stop Mode

If the Count mode field is set to 000, the counter is inert. No counting will occur.

12.7.2 Count Mode

If the Count mode field is set to 001, the counter will count the rising edges of the selected clock source. This mode is useful for generating periodic interrupts for timing purposes, or counting external events such as *widgets* on a conveyor belt passing a sensor. If the selected input is inverted by setting the Input Polarity Select (IPS) bit, the negative edge of the selected external input signal is counted.

12.7.3 Edge Count Mode

If the Count mode field is set to 010, the counter will count both edges of the selected external clock source. This mode is useful for counting the changes in the external environment such as a simple encoder wheel.

12.7.4 Gated Count Mode

If the Count mode field is set to 011, the counter will count while the selected secondary input signal is high. This mode is used to time the duration of external events. If the selected input is inverted by setting the Input Polarity Select (IPS) bit, the counter will count while the selected secondary input is low.

12.7.5 Quadrature Count Mode

When the Count mode field is set to 100, the counter will decode the primary and secondary external inputs as quadrature encoded signals. Quadrature signals are usually generated by rotary or linear sensors used to monitor movement of motor shafts or mechanical equipment. The quadrature signals are square waves, 90 degrees out-of-phase. The decoding of quadrature signal provides both count and direction information. A timing diagram illustrating the basic operation of a quadrature incremental position encoder is provided in **Figure 12-2.**

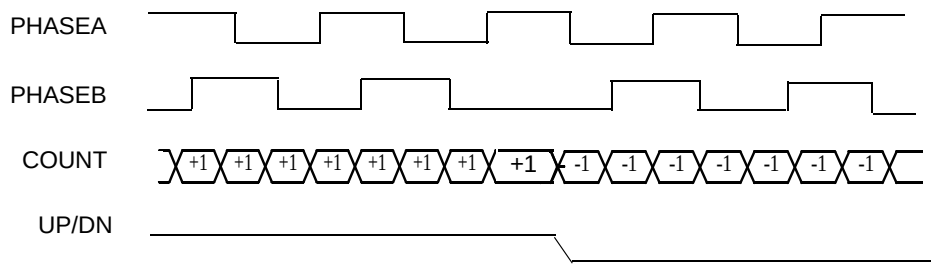


Figure 12-2. Quadrature Incremental Position Encoder

12.7.6 Signed Count Mode

If the Count mode field is set to 101, the counter counts the primary clock source while the selected secondary source provides the selected count direction (up/down).

12.7.7 Triggered Count Mode

If the Count mode field is set to 110, the counter will begin counting the primary clock source after a positive transition (Negative Edge if IPS = 1) of the secondary input occurs. The counting will continue until a compare event occurs, or another positive input transition is detected. If a second input transition occurs before a terminal count was reached, counting will stop. Subsequent odd numbered edges of the secondary input will restart counting, while even numbered edges will stop counting. This will continue until a compare event occurs.

12.7.8 One-Shot Mode

This is a sub mode of triggered event Count mode if the count mode field is set to 110 while:

- Count Length (LENGTH) is set
- OFLAG Output mode is set to 101
- ONCE bit of the Control Register (CTRL) is set to 1

In the above setting, the counter works in a One-Shot mode. An external event causes the counter to count. When terminal count is reached, the OFLAG output is asserted. This delayed output assertion can be used to provide timing delays.

12.7.9 Cascade Count Mode

If the Count mode field is set to 111, the counter's input is connected to the output of another selected counter. The counter will count up and down as compare events occur in the selected source counter. This Cascade or Daisy-Chained mode enables multiple counters to be cascaded in order to yield longer counter lengths. When operating in the Cascade mode, a special high speed signal path is used not using the OFLAG Output signal. If the Selected Source Counter is counting up, and it experiences a compare event, the counter will be incremented. If the selected source counter is counting down and it experiences a compare event, the counter will be decremented. Up to four counters may be cascaded to create a 64-bit wide synchronous counter. Whenever any counter is read within a Counter module, all of the counters' values within the module are captured in their respective Hold Registers. This action supports the reading of a cascaded counter chain. First read any counter of a cascaded counter chain, then read the Hold Registers of the other counters in the chain. The Cascaded Counter mode is synchronous.

Note: It is possible to connect counters together by using the other (non-cascade) Counter modes and selecting the outputs of other counters as a clock source. In this case, the counters are operating in a *ripple* mode, where higher order counters will transition a clock later than a purely synchronous design.

12.7.10 Pulse Output Mode

The Counter will output a pulse stream of pulses with the same frequency of the selected clock source (can not be IPBus clock divided by one) if the counter is setup for:

- Count mode (mode = 001)
- The OFLAG Output mode is set to 111 (Gated Clock Output)
- The Count Once bit is set

The number of output pulses is equal to the compare value minus the initial value. This mode is useful for driving step motor systems.

Note: Primary Count Source must be set to one of the counter outputs for gated clock output mode.

12.7.11 Fixed Frequency PWM Mode

The Counter output yields a Pulse Width Modulated (PWM) signal with a frequency equal to the count clock frequency divided by 65,536. It has a pulse width duty cycle equal to the compare value divided by 65,536 if the counter is setup for:

- Count mode (mode = 001)
- Count through roll-over (Count Length = 0)
- Continuous count (Count Once = 0)
- OFLAG Output mode is 110 (set on compare, cleared on counter rollover)

This mode of operation is often used to drive PWM amplifiers used to power motors and inverters.

12.7.12 Variable Frequency PWM Mode

If the counter is setup for:

- Count mode (Mode = 001)
- Count till compare (Count Length = 1)
- Continuous count (Count Once = 0)
- OFLAG Output mode is 100 (toggle OFLAG and alternate compare registers)

the counter output yields a Pulse Width Modulated (PWM) signal whose frequency and pulse width is determined by the values programmed into the TMR_CMP1 and TMR_CMP2 registers, and the input clock frequency. This method of PWM generation has the advantage of allowing almost any desired PWM frequency and/or constant on or off periods. This mode of operation is often used to drive PWM amplifiers used to power motors and inverters.

12.7.13 Compare Registers Use

The dual Compare registers (TMR_CMP1 and TMR_CMP2) provide a bidirectional modulo count capability. The CMP1 Register is used when the counter is counting *up*, and the CMP2 Register is used when the counter is counting *down*. The only exception is when the counter is operating with alternating compare registers. The CMP1 Register should be set to the desired maximum count value or $FFFF to indicate the maximum unsigned value prior to roll-over, and the CMP2 Register should be set to the maximum negative count value or $0000 indicating the maximum unsigned value prior to roll-under.

If the Output mode is set to 100, the OFLAG will toggle while using alternating Compare registers. In this Variable Frequency PWM mode, the CMP2 value defines the desired pulse width of the *on-time*, and the CMP1 Register defines the *off-time*. The Variable Frequency PWM mode is defined for positive counting only.

One must be careful when changing CMP1 and CMP2 while the counter is active. If the counter has already passed the new value, it will count to $FFFF or $0000, roll over/under, and then begin counting toward the new value. (The check is for Count = Cmpx, not Count> = Cmp1 or Count < = Cmp2).

12.7.14 Capture Register Use

The Capture Register stores a copy of the counter’s value when an input edge (positive, negative, or both) is detected. Once a capture event occurs, no further updating of the Capture Register will occur until the Input Edge Flag (IEF) is cleared by writing 0 to the IEF.

12.8 Module Memory Map

There are eight registers on the TMR peripheral described in **Table 12-1.**

Table 12-1. TMR Module Memory Map (TMR_BASE = $1FFE80)

Address Offset	Register Acronym	Register Name	Access Type	Chapter Location
Base + $0, $8, $10, $18	CMP1	Timer Channel 0 Compare Register 1	Read/Write	Section 12.9.3
Base + $1, $9, $11, $19	CMP2	Timer Channel 0 Compare Register 2	Read/Write	Section 12.9.4
Base + $2, $A, $12, $1A	CAP	Timer Channel 0 Capture Register	Read/Write	Section 12.9.5
Base + $3, $B, $13, $1B	LOAD	Timer Channel 0 Load Register	Read/Write	Section 12.9.6
Base + $4, $C, $14, $1C	HOLD	Timer Channel 0 Hold Register	Read/Write	Section 12.9.7
Base + $5, $D, $15, $1D	CNTR	Timer Channel 0 Counter Register	Read/Write	Section 12.9.8
Base + $6, $E, $16, $1E	CTRL	Timer Channel 0 Control Register	Read/Write	Section 12.9.1
Base + $7, $F, $17, $1F	SCR	Timer Channel 0 Status/Control Reg.	Read/Write	Section 12.9.2

Add. Offset	Register Name		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$0, $8, $10, $18	CMP1	R	COMPARISON VALUE															
		W																
$1, $9, $11, $19	CMP2	R	COMPARISON VALUE															
		W																
$2, $A, $12, $1A	CAP	R	CAPTURE VALUE															
		W																
$3, $B, $13, $1B	LOAD	R	LOAD VALUE															
		W																
$4, $C, $14, $1C	HOLD	R	HOLD VALUE															
		W																
$5, $D, $15, $1D	CNTR	R	COUNTER															
		W																
$6, $E, $16, $1E	CTL	R	COUNT MODE			PRIMARY COUNT SOURCE				SECONDARY SOURCE		ONCE	LENGTH	DIR	EXT INIT	OUTPUT (OFLAG) MODE		
		W																
$7, $F, $17, $1F	SCR	R	TCF	TCFIE	TOF	TOFIE	IEF	IEFIE	IPS	INPUT	CAPTURE MODE		MSTR	EEOF	VAL		OPS	OEN
																FORCE		

R 0 Read as 0
W Reserved

Figure 12-3. TMR Register Map Summary

12.9 Register Descriptions (TMR_BASE = $1FFE80)

12.9.1 Timer Control Registers (CTL)

There are four Timer Control Registers in this occurrence. Their addresses are:

TMRA0_CTRL (Timer A, Channel 0 Control)—Address: TMRA_BASE + $6
TMRA1_CTRL (Timer A, Channel 1 Control)—Address: TMRA_BASE + $E
TMRA2_CTRL (Timer A, Channel 2 Control)—Address: TMRA_BASE + $16
TMRA3_CTRL (Timer A, Channel 3 Control)—Address: TMRA_BASE + $1E

Base + $6, $E, $16, $1E	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	CM			PCS				SCS		ONCE	LENGTH	DIR	EXT INIT	OM (OFLAG)		
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 12-4. TMR Control Register (CTL)

See Programmer's Sheet on Appendix page B-65

12.9.1.1 Count Mode (CM)—Bits 15–13

These bits control the basic counting behavior of the counter.

- 000 = No operation
- 001 = Count rising edges of primary source[1]
- 010 = Count rising and falling edges of primary source
- 011 = Count rising edges of primary source while secondary input high active[1]
- 100 = Quadrature count mode, uses primary and secondary sources
- 101 = Count rising edges of primary source; secondary source specifies direction (1 = minus)[1]
- 110 = Edge of secondary source triggers primary count until compare
- 111 = Cascaded Counter mode (up/down)[2]

12.9.1.2 Primary Count Source (PCS)—Bits 12–9

These bits select the Primary Count Source.

- 0000 = Counter 0 pin (TIO0)
- 0001 = Counter 1 pin (TIO1)
- 0010 = Counter 2 pin (TIO2)

1. Rising edges counted only when IPS = 0. Falling edges counted when IPS = 1.
2. Primary Count Source must be set to one of the counter outputs.

- 0011 = Counter 3 pin (TIO3)
- 0100 = Counter 0 OFLAG
- 0101 = Counter 1 OFLAG
- 0110 = Counter 2 OFLAG
- 0111 = Counter 3 OFLAG
- 1000 = Prescaler (IPBus clock divide by 1)
- 1001 = Prescaler (IPBus clock divide by 2)
- 1010 = Prescaler (IPBus clock divide by 4)
- 1011 = Prescaler (IPBus clock divide by 8)
- 1100 = Prescaler (IPBus clock divide by 16)
- 1101 = Prescaler (IPBus clock divide by 32)
- 1110 = Prescaler (IPBus clock divide by 64)
- 1111 = Prescaler (IPBus clock divide by 128)

Note: A timer selecting its own output for input is not a legal choice. The result is no counting.

12.9.1.3 Secondary Count Source (SCS)—Bits 8–7

These bits provide additional information, such as direction, used for counting. They also define the source used by both the Capture mode bits and the Input Edge Flag in the Channel Status and Control register.

- 00 = Counter 0 pin (TIO0)
- 01 = Counter 1 pin (TIO1)
- 10 = Counter 2 pin (TIO2)
- 11 = Counter 3 pin (TIO3)

12.9.1.4 Count Once (ONCE)—Bit 6

This bit select continuous or one shot counting mode.

- 0 = Count repeatedly
- 1 = Count until compare and then stop. If *counting up*, successful compare occurs when counter reaches CMP1 value. If *counting down*, successful compare occurs when counter reaches CMP2 value. When the compare occurs the timer is stopped by changing the timer's Count mode to *Stop Mode* (CM=0).

12.9.1.5 Count Length (LENGTH)—Bit 5

This bit determines whether the counter counts to the compare value and then reinitializes itself, or the counter continues counting past the compare value (binary roll-over).

- 0 = Roll-over
- 1 = Count till compare, then reinstalled. If counting up, successful compare occurs when counter reaches CMP1 value. If counting down, successful compare occurs when counter reaches CMP2 value.[1]

12.9.1.6 Count Direction (DIR)—Bit 4

This bit selects either the normal count up direction, or the reverse down direction.

- 0 = Count Up
- 1 = Count Down

12.9.1.7 External Initialization (EXT INIT)—Bit 3

This bit enables another counter/timer within the same module to force the re-initialization of this counter/timer when the other counter has an active compare event.

- 0 = External counter/timers can not force a re-initialization of this counter/timer.
- 1 = External counter/timers may force a re-initialization of this counter/timer.

12.9.1.8 Output Mode (OM)—Bits 2–0

These bits determine the mode of operation for the OFLAG output signal.

- 000 = Asserted while counter is active
- 001 = Clear OFLAG output on successful compare
- 010 = Set OFLAG output on successful compare
- 011 = Toggle OFLAG output on successful compare
- 100 = Toggle OFLAG output using alternating compare registers
- 101 = Set on compare, cleared on secondary source input edge
- 110 = Set on compare, cleared on counter rollover
- 111 = Enable Gated Clock output while counter is active[2]

1. When the Output mode 0×4 is used, alternating values of CMP1 and CMP2 are used to generate successful compares. For example, when the Output mode is 0×4, the counter counts until CMP1 value is reached, reinitializes, then counts until CMP2 value is reached, reinitializes, then counts until CMP1 value is reached, and so on.
2. Primary Count Source must be set to one of the counter outputs

2. Primary Count Source must be set to one of the counter outputs.

Note: Unexpected results may occur if the Output mode field is set to use alternating Compare registers (mode 100) and the Count Once bit is set.

12.9.2 Timer Channel Status and Control Registers (SCR)

There are four Timer Status and Control Registers in this occurrence. Their addresses are:

TMRA0_SCR (Timer A, Channel 0 Status and Control)—Address: TMRA_BASE + $7
TMRA1_SCR (Timer A, Channel 1 Status and Control)—Address: TMRA_BASE + $F
TMRA2_SCR (Timer A, Channel 2 Status and Control)—Address: TMRA_BASE + $17
TMRA3_SCR (Timer A, Channel 3 Status and Control)—Address: TMRA_BASE + $1F

Base + $7, $F, $17, $1F	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	TCF	TCFIE	TOF	TOFIE	IEF	IEFIE	IPS	INPUT	CAPTURE MODE		MSTR	EEOF	VAL	0	OPS	OEN
Write														FORCE		
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 12-5. TMR Status and Control Register (SCR)

See Programmer's Sheet on Appendix page B-68

12.9.2.1 Timer Compare Flag (TCF)—Bit 15

This bit is set when a successful compare occurs. Clear the bit by writing 0 to it.

12.9.2.2 Timer Compare Flag Interrupt Enable (TCFIE)—Bit 14

When set, this bit enables interrupts when the TCF bit is set.

12.9.2.3 Timer Overflow Flag (TOF)—Bit 13

This bit is set when the counter rolls over its maximum value $FFFF or $0000, depending on count direction. Clear the bit by writing 0 to it.

12.9.2.4 Timer Overflow Flag Interrupt Enable (TOFIE)—Bit 12

When set, this bit enables interrupts when the TOF bit is set.

12.9.2.5 Input Edge Flag (IEF)—Bit 11

This bit is set when a positive input transition occurs while the counter is enabled. Clear the bit by writing 0 to it.

Note: Setting the input polarity select (IPS) bit enables the detection of negative input edge transitions detection. Also, the control register's Secondary Count Source determines which external input pin is monitored by the detection circuitry.

12.9.2.6 Input Edge Flag Interrupt Enable (IEFIE)—Bit 10

When set, this bit enables interrupts when the IEF bit is set

12.9.2.7 Input Polarity Select (IPS)—Bit 9

When set, this bit inverts the polarity of both the primary and secondary inputs..

12.9.2.8 External Input Signal (INPUT)—Bit 8

This bit reflects the current state of the external input pin selected via the Secondary Count Source after application of the IPS bit. This is a *read-only* bit.

12.9.2.9 Input Capture Mode (Capture Mode)—Bits 7–6

These bits specify the operation of the Capture Register as well as the operation of the input edge flag.

- 00 = Capture function is disabled.
- 01 = Load Capture register on rising edge of input
- 10 = Load Capture Register on falling edge of input
- 11 = Load Capture Register on any edge of input

12.9.2.10 Master Mode (MSTR)—Bit 5

When set, this bit enables the Compare function’s output to be broadcasted to the other counter/timers in the module. This signal then can be used to reinitialize the other counters and/or force their OFLAG signal outputs.

12.9.2.11 Enable External OFLAG Force (EEOF)—Bit 4

When set, this bit enables the compare from another counter/timer within the same module to force the state of this counters’ OFLAG Output signal.

12.9.2.12 Forced OFLAG Value (VAL)—Bit 3

This bit determines the value of the OFLAG Output signal when a software triggered FORCE command occurs.

12.9.2.13 Force OFLAG Output (FORCE)—Bit 2

This *write-only* bit forces the current value of the VAL bit to be written to the OFLAG Output. Always read this bit as 0. The VAL and FORCE bits can be written simultaneously in a single write operation. Write to the FORCE bit only if the counter is disabled.

- 0 = No action
- 1 = Forces the current value of the VAL bit to be written to OFLAG Output

Note: Setting this bit while the counter is enabled may yield unpredictable results.

12.9.2.14 Output Polarity Select (OPS)—Bit 1

This bit determines the polarity of the OFLAG Output signal.

- 0 = True polarity
- 1 = Inverted polarity

12.9.2.15 Output Enable (OEN)—Bit 0

When set, this bit enables the OFLAG Output signal to be put on the external pin. Additionally, setting this bit connects a timer's output pin to its input. The polarity of the signal will be determined by the OPS bit.

12.9.3 Timer Channel Compare Register 1 (CMP1)

These read/write registers store the value used for comparison with counter value. There are four Timer Channel Compare Registers in this occurrence. Their addresses are:

TMRA0_CMP1 (Timer A, Channel 0 Compare 1)—Address:TMRA_BASE + $0
TMRA1_CMP1 (Timer A, Channel 1 Compare 1)—Address: TMRA_BASE + $8
TMRA2_CMP1 (Timer A, Channel 2 Compare 1)—Address:TMRA_BASE + $10
TMRA3_CMP1 (Timer A, Channel 3 Compare 1)—Address: TMRA_BASE + $18

Base + $0. $8, $10, $18	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	COMPARISON VALUE 1															
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 12-6. TMR Compare Register 1 (CMP1)

See Programmer's Sheet on Appendix page B-70

12.9.4 Timer Channel Compare Register 2 (CMP2)

These read/write registers store the value used for comparison with counter value. There are four Timer Compare Registers in this occurrence. Their addresses are:

TMRA0_CMP2 (Timer A, Channel 0 Compare 2)—Address: TMRA_BASE + $1
TMRA1_CMP2 (Timer A, Channel 1 Compare 2)—Address: TMRA_BASE + $9
TMRA2_CMP2 (Timer A, Channel 2 Compare 2)—Address: TMRA_BASE + $11
TMRA3_CMP2 (Timer A, Channel 3 Compare 2)—Address: TMRA_BASE + $19

Base + $1, $9, $11, $19	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	COMPARISON VALUE 2															
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 12-7. TMR Compare Register 2 (CMP2)

See Programmer's Sheet on Appendix page B-71

12.9.5 Timer Channel Capture Register (CAP)

These read/write registers store the values captured from the counters. There are four Timer Channel Hold Registers in this occurrence. Their addresses are:

TMRA0_CAP (Timer A, Channel 0 Capture)—Address: TMRA_BASE + $2
TMRA1_CAP (Timer A, Channel 1 Capture)—Address: TMRA_BASE + $A
TMRA2_CAP (Timer A, Channel 2 Capture)—Address: TMRA_BASE + $12
TMRA3_CAP (Timer A, Channel 3 Capture)—Address: TMRA_BASE + $1A

Base + $2, $A, $12, $1A	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	CAPTURE VALUE															
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 12-8. TMR Capture Register (CAP)

See Programmer's Sheet on Appendix page B-72

12.9.6 Timer Channel Load Register (LOAD)

These read/write registers store the value used to load the counter. There are four Timer Channel Load Registers in this occurrence. Their addresses are:

TMRA0_LOAD (Timer A, Channel 0 Load)—Address: TMRA_BASE + $3
TMRA1_LOAD (Timer A, Channel 1 Load)—Address: TMRA_BASE + $B
TMRA2_LOAD (Timer A, Channel 2 Load)—Address: TMRA_BASE + $13
TMRA3_LOAD (Timer A, Channel 3 Load)—Address: TMRA_BASE + $1B

Base + $3, $B, $13, $1B	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	LOAD VALUE															
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 12-9. TMR Load Register (LOAD)

See Programmer's Sheet on Appendix page B-73

12.9.7 Timer Channel Hold Register (HOLD)

These read/write registers store the channel's value whenever any counter is read. There are four Timer Channel Hold Registers in this occurrence. Their addresses are:

TMRA0_HOLD (Timer A, Channel 0 Load)—Address: TMRA_BASE + $4
TMRA1_HOLD (Timer A, Channel 1 Load)—Address: TMRA_BASE + $C
TMRA2_HOLD (Timer A, Channel 2 Load)—Address: TMRA_BASE + $14
TMRA3_HOLD (Timer A, Channel 3 Load)—Address: TMRA_BASE + $1C

Base + $4, $C, $14, $1C	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	HOLD VALUE															
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 12-10. TMR Hold Register (HOLD)

See Programmer's Sheet on Appendix page B-74

12.9.8 Timer Channel Counter Register (CNTR)

These read/write registers are counters. There are four Timer Channel Counter Registers in this occurrence. Their addresses are:

TMRA0_CNTR (Timer A, Channel 0 Counter)—Address: TMRA_BASE + $5
TMRA1_CNTR (Timer A, Channel 1 Counter)—Address: TMRA_BASE + $D
TMRA2_CNTR (Timer A, Channel 2 Counter)—Address: TMRA_BASE + $15
TMRA3_CNTR (Timer A, Channel 3 Counter)—Address: TMRA_BASE + $1D

Base + $5. $D, $15, $1D	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	COUNTER															
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 12-11. TMR Counter Register (CNTR)

See Programmer's Sheet on Appendix page B-75

12.10 Resets

The TMR module can only be reset by the $\overline{\text{RST}}$ signal. This forces all registers to their reset state and clears the OFLAG signal if it is asserted. The counter will be turned off until the settings in the Control register are changed.

12.11 Interrupts

The TMR module can generate 12 interrupts, three for each of the four counters/channels.

12.11.1 Timer Compare Interrupts

These interrupts are generated when a successful compare occurs between a counter and it's compare registers while the Timer Compare Flag Interrupt Enable (TCFIE) is set in the TMR_SCR. These interrupts are cleared by writing 0 to the TCF bit in the appropriate TMR_SCR.

12.11.2 Timer Overflow Interrupts

These interrupts are generated when a counter rolls over its maximum value while the TCFIE bit is set in the TMR_SCR. These interrupts are cleared by writing 0 to the Timer Overflow Flag (TOF) bit of the appropriate TMR_SCR.

12.11.3 Timer Input Edge Interrupts

These interrupts are generated by a transition of the input signal (either positive or negative depending on IPS setting) while the Input Edge Flag Interrupt Enable (IEFIE) bit is set in the TMR_SCR. These interrupts are cleared by writing 0 to the IEF bit of the appropriate TMR_SCR.

Chapter 13
General Purpose Input/Output (GPIO)

13.1 Introduction

The 56852 General Purpose Input/Output (GPIO) is designed to share package pins with other peripheral modules on the chip. If a peripheral normally controlling a given pin is not required, then the pin can be programmed to be a GPIO with programmable pull-up.

13.2 Features

The GPIO module design includes:

- Individual control for each pin to be in either Normal or GPIO mode
- Individual direction control for each pin in GPIO mode
- Individual pull-up enable control for each pin in either Normal or GPIO mode

13.3 GPIO Block Diagram

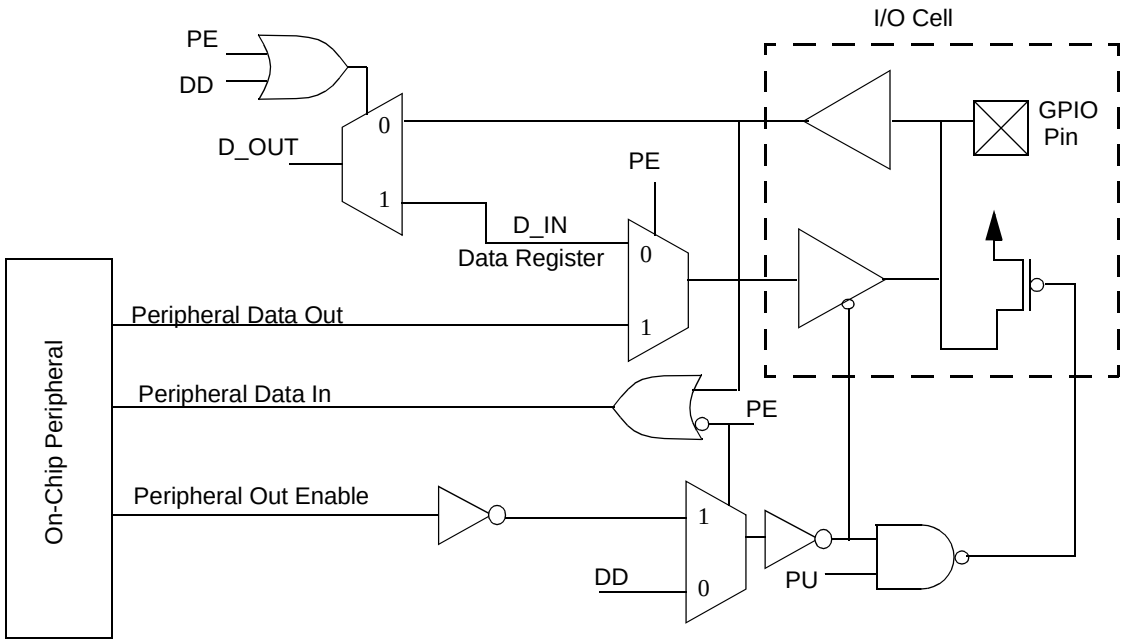


Figure 13-1. Bit-Slice View of GPIO Logic

Table 13-1. Mapping of External Signals to GPIO Ports

Peripheral	Functional Signal	GPIO Port	GPIO Bit
EMI	$\overline{CS2}$	A	2
EMI	$\overline{CS1}$	A	1
EMI	$\overline{CS0}$	A	0
SPI	MOSI	C	5
SPI	MISO	C	4
SPI	$\overline{SS}$	C	3
ISSI	SCLK	C	2
ISSI	SRXD	C	1
ISSI	STXD	C	0
SCI	TXD	E	1
SCI	RXD	E	0

13.4 Functional Description

Each GPIO pin can be configured as either an input, with or without pull-up, or an output. Pull-ups are configured by writing to the Pull-Up Registers and are automatically disabled when the pin is being used as an output in either the Normal or GPIO modes of operation.

13.5 Modes of Operation

The GPIO module design contains two major modes of operation:

13.5.1 Normal Mode

This can also be thought of as Peripheral Controlled mode. The peripheral module controls the output enable and any output data to the I/O pad and any input data from the pad is passed to the peripheral. Pull-up enables are controlled by a GPIO register.

13.5.2 GPIO Mode

In this mode, the GPIO module controls the output enable to the pad and supplies any data to be output. Also, any input data can be read from a GPIO memory mapped register. Pull-up enables are controlled by a GPIO register.

In the GPIO mode, the Data Direction Register (DDR) supplies the output enable to the I/O pad to control its direction. The DR supplies the output data if DDR is asserted. The value of the data on the I/O pad can be read by reading Data Register (DR) when DDR is zero. When in GPIO mode the output data from the GPIO to the peripheral module will be driven high and the output data and enable from the peripheral are ignored. The pull-up resistor can be enabled by writing to the PUE Register. The pull-up resistor will be disabled as long as the DDR is set to the Output mode.

13.6 GPIO Configurations

Each GPIO port is controlled by the registers listed in **Section 13-2.** Each register bit corresponds to a GPIO pin. **Figure 13-1** illustrates the logic associated with one GPIO bit.

Table 13-2. GPIO Registers Functions

Register	Description	Function
PER	Peripheral Enable Register	Determines if pin functions as GPIO or associated peripheral pin
DDR	Data Direction Register	Determines pin direction (input or output) when pin functions as GPIO
DR	Data Register	Data interface between the GPIO pin and the IPBus
PUER	Pull-Up Enable Register	Enables internal pull-up, qualified by other factors

13.7 Module Memory Maps

There are three GPIO mapped modules listed in the following in tables, **Section 13-3** through **Section 13-5.** The GPIO peripherals are summarized in **Figure 13-2** through **Figure 13-4.**

Table 13-3. GPIO A Memory Map (GPIOA_BASE = $1FFE60)

Address Offset	Register Acronym	Register Name	Access Type	Chapter Location
Base + $0	GPIO_A_PER	Peripheral Enable Register	Read/Write	**Section 13.8.1**
Base + $1	GPIO_A_DDR	Data Direction Register	Read/Write	**Section 13.8.4**
Base + $2	GPIO_A_DR	Data Register	Read/Write	**Section 13.8.7**
Base + $3	GPIO_A_PUR	Pull-Up Enable Register	Read/Write	**Section 13.8.10**

Add. Offset	Register Name		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$0	PER	R	1	1	1	1	1	1	1	1	1	1	1	1	1	PE		
		W																
$1	DDR	R	0	0	0	0	0	0	0	0	0	0	0	0	0	DD		
		W																
$2	DR	R	0	0	0	0	0	0	0	0	0	0	0	0	0	DATA		
		W																
$3	PUR	R	1	1	1	1	1	1	1	1	1	1	1	1	1	1	PUE	
		W																

R	0	Read as 0
W		Reserved

Figure 13-2. GPIO A Register Map Summary

Table 13-4. GPIO C Memory Map (GPIOC_BASE = $1FFE68)

Address Offset	Register Acronym	Register Name	Access Type	Chapter Location
Base + $8	GPIO_C_PER	Peripheral Enable Register	Read/Write	Section 13.8.2
Base + $9	GPIO_C_DDR	Data Direction Register	Read/Write	Section 13.8.5
Base + $A	GPIO_C_DR	Data Register	Read/Write	Section 13.8.8
Base + $B	GPIO_C_PUR	Pull-Up Enable Register	Read/Write	Section 13.8.11

Add. Offset	Register Name		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$8	PER	R	1	1	1	1	1	1	1	1	1	1	PE					
		W																
$9	DDR	R	0	0	0	0	0	0	0	0	0	0	DD					
		W																
$A	DR	R	0	0	0	0	0	0	0	0	0	0	DATA					
		W																
$B	PUR	R	1	1	1	1	1	1	1	1	1	1	PUE					
		W																

R	0	Read as 0
W		Reserved

Figure 13-3. GPIO C Register Map Summary

Table 13-5. GPIO E Memory Map (GPIOE_BASE = $1FFE70)

Address Offset	Register Acronym	Register Name	Access Type	Chapter Location
Base + $16	GPIO_E_PER	Peripheral Enable Register	Read/Write	Section 13.8.3
Base + $17	GPIO_E_DDR	Data Direction Register	Read/Write	Section 13.8.6
Base + $18	GPIO_E_DR	Data Register	Read/Write	Section 13.8.9
Base + $19	GPIO_E_PUR	Pull-Up Enable Register	Read/Write	Section 13.8.12

Add. Offset	Register Name		15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$16	PER	R	1	1	1	1	1	1	1	1	1	1	1	1	1	1	PE	
		W																
$17	DDR	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	DD	
		W																
$18	DR	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	DATA	
		W																
$19	PUR	R	1	1	1	1	1	1	1	1	1	1	1	1	1	1	PUE	
		W																

R 0 Read as 0
W Reserved

Figure 13-4. GPIO E Register Map Summary

13.8 Register Descriptions

Base Addresses:

- GPIOA_BASE = $1FFE60
- GPIOC_BASE = $1FFE68
- GPIOE_BASE = $1FFE70

13.8.1 Port A Peripheral Enable Register (GPIOA_PER)

Base + $0	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	1	1	1	1	1	1	1	1	1	1	1	1	1	PE		
Write																
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 13-5. Port A Peripheral Enable Register (GPIOA_PER)

See Programmer's Sheet on Appendix page B-76

13.8.1.1 Reserved—Bits 15–3

These bits are reserved or not implemented. They are read as 1 and cannot be modified by writing.

13.8.1.2 Peripheral Enable (PE)—Bits 2–0

These bits control whether a given pin is in either Normal or GPIO mode.

- 0 = GPIO mode; pin operation is controlled by GPIO registers
- 1 = Normal mode; pin operation is controlled by the EMI module

13.8.2 Port C Peripheral Enable Register (GPIOC_PER)

Base + $8	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	1	1	1	1	1	1	1	1	1	1	PE					
Write																
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 13-6. Port C Peripheral Enable Register (GPIOC_PER)

See Programmer's Sheet on Appendix page B-77

13.8.2.1 Reserved—Bits 15–6

These bits are reserved or not implemented. They are read as 1 and cannot be modified by writing.

13.8.2.2 Peripheral Enable (PE)—Bits 5–0

These bits control whether a given pin is in either Normal or GPIO mode.

- 0 = GPIO mode; pin operation is controlled by GPIO registers
- 1 = Normal mode; pin operation is controlled by the SPI or ISSI modules

13.8.3 Port E Peripheral Enable Register (GPIOE_PER)

Base + $16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	1	1	1	1	1	1	1	1	1	1	1	1	1	1	PE	
Write																
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 13-7. Port E Peripheral Enable Register (GPIOE_PER)

See Programmer's Sheet on Appendix page B-78

13.8.3.1 Reserved—Bits 15–2

These bits are reserved or not implemented. They are read as 1 and cannot be modified by writing.

13.8.3.2 Peripheral Enable (PE)—Bits 1–0

These bits control whether a given pin is in either Normal or GPIO mode.

- 0 = GPIO mode; pin operation is controlled by GPIO registers
- 1 = Normal mode; pin operation is controlled by the SCI module

13.8.4 Port A Data Direction Register (GPIOA_DDR)

Base + $1	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	0	0	0	0	0	DD		
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 13-8. Port A Data Direction Register (GPIOA_DDR)

See Programmer's Sheet on Appendix page B-79

13.8.4.1 Reserved—Bits 15–3

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

13.8.4.2 Data Direction (DDR)—Bits 2–0

These bits control the pins direction when in GPIO mode. In the Normal mode, these bits have no effect on the output enables or pull-up enables.

- 0 = Pin is an input; pull-ups are dependent on value of PUE registers (default)
- 1 = Pin is an output; pull-ups are disabled

13.8.5 Port C Data Direction Register (GPIOC_DDR)

Base + $9	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	0	0	DD					
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 13-9. Port C Data Direction Register (GPIOC_DDR)

See Programmer's Sheet on Appendix page B-80

13.8.5.1 Reserved—Bits 15–6

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

13.8.5.2 Data Direction (DDR)—Bits 5–0

These bits control the pins direction when in the GPIO mode. In the Normal mode, these bits have no effect on the output enables or pull-up enables.

- 0 = Pin is an input; pull-ups are dependent on value of PUE registers (default)
- 1 = Pin is an output; pull-ups are disabled

13.8.6 Port E Data Direction Register (GPIOE_DDR)

Base + $17	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	0	0	0	0	0	0	DD	
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 13-10. Port E Data Direction Register (GPIOE_DDR)

See Programmer's Sheet on Appendix page B-79

13.8.6.1 Reserved—Bits 15–2

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

13.8.6.2 Data Direction (DDR)—Bits 1–0

These bits control the pins direction when in the GPIO mode. In the Normal mode, these bits have no effect on the output enables or pull-up enables.

- 0 = Pin is an input; pull-ups are dependent on value of PUE registers (default)
- 1 = Pin is an output; pull-ups are disabled

13.8.7 Port A Data Register (GPIOA_DR)

Base + $2	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	0	0	0	0	0	DATA		
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 13-11. Port A Data Register (GPIOA_DR)

See Programmer's Sheet on Appendix page B-82

13.8.7.1 Reserved—Bits 15–3

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

13.8.7.2 Data (DATA)—Bits 2–0

These bits control the output data when in the GPIO mode.

13.8.8 Port C Data Register (GPIOC_DR)

Base + $A	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	0	0	DATA					
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 13-12. Port C Data Register (GPIOC_DR)

See Programmer's Sheet on Appendix page B-83

13.8.8.1 Reserved—Bits 15–6

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

13.8.8.2 Data (DATA)—Bits 5–0

These bits control the output data when in the GPIO mode.

13.8.9 Port E Data Register (GPIOE_DR)

Base + $18	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	0	0	0	0	0	0	0	0	0	0	0	0	0	DATA	
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 13-13. Port E Data Register (GPIOE_DR)

See Programmer's Sheet on Appendix page B-84

13.8.9.1 Reserved—Bits 15–2

These bits are reserved or not implemented. They are read as 0 and cannot be modified by writing.

13.8.9.2 Data (DATA)—Bits 1–0

These bits control the output data when in the GPIO mode.

13.8.10 Port A Pull-Up Enable Register (GPIOA_PUE)

Base + $3	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	1	1	1	1	1	1	1	1	1	1	1	1	1	PE		
Write																
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 13-14. Port A Pull-Up Enable Register (GPIOA_PUE)

See Programmer's Sheet on Appendix page B-85

13.8.10.1 Reserved—Bits 15–3

These bits are reserved or not implemented. They are read as 1 and cannot be modified by writing.

13.8.10.2 Pull-Up Enable (PULLUP)—Bits 2–0

These bits control whether pull-ups are enabled for inputs in either Normal or GPIO modes. Pull-ups are automatically disabled for outputs in both modes.

- 0 = Pull-ups disabled for inputs
- 1 = Pull-ups enabled for inputs (default)

13.8.11 Port C Pull-Up Enable Register (GPIOC_PUE)

Base + $B	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	1	1	1	1	1	1	1	1	1	1	PE					
Write																
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 13-15. Port C Pull-Up Enable Register (GPIOC_PUE)

See Programmer's Sheet on Appendix page B-86

13.8.11.1 Reserved—Bits 15–6

These bits are reserved or not implemented. They are read as 1 and cannot be modified by writing.

13.8.11.2 Pull-Up Enable (PULLUP)—Bits 5–0

These bits control whether pull-ups are enabled for inputs in either Normal or GPIO modes. Pull-ups are automatically disabled for outputs in both modes.

- 0 = Pull-ups disabled for inputs
- 1 = Pull-ups enabled for inputs (default)

13.8.12 Port E Pull-Up Enable Register (GPIOE_PUE)

Base + $19	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	1	1	1	1	1	1	1	1	1	1	1	1	1	1	PE	
Write																
Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 13-16. Port E Pull-Up Enable Register (GPIOE_PUE)

See Programmer's Sheet on Appendix page B-87

13.8.12.1 Reserved—Bits 15–2

These bits are reserved or not implemented. They are read as 1 and cannot be modified by writing.

13.8.12.2 Pull-Up Enable (PULLUP)—Bits 1–0

These bits control whether pull-ups are enabled for inputs in either Normal or GPIO modes. Pull-ups are automatically disabled for outputs in both modes.

- 0 = Pull-ups disabled for inputs
- 1 = Pull-ups enabled for inputs (default)

13.9 Data Register Access

Care must be taken when accessing the Data Registers. **Section 13-6** summarizes the results of various Data Register accesses in different conditions.

Table 13-6. Data Register Access

Output Enable from Peripheral	PER	DDR	Pin State	Access Type	Data Access Result
X	0	0	Input	Write to DR	Data is written into DR by IPBus. No effect on the pin value.
X	0	1	Output	Write to DR	Data is written into the DR by the IPBus. DR value seen at pin.
X	0	0	Input	Read from DR	pin state is read by the IPBus. No effect on DR value.
X	0	1	Output	Read from DR	DR value is read by the IPBus. DR value seen at pin.
1	1	X	Input	Write to DR	Data is written into the DR by the IPBus. No effect on pin value.
0	1	X	Output	Write to DR	Data is written into the DR by the IPBus. Peripheral output data is seen at pin.
1	1	X	Input	Read from DR	DR value is read by the IPBus. No effect on the pin or DR value.
0	1	X	Output	Read from DR	DR value is read by the IPBus. Peripheral output data is seen at the pin.

13.10 Resets

The GPIO module can only be reset by the $\overline{\text{RST}}$ signal. This forces all registers to their reset state, setting the chip pins to be peripheral controlled with pull-ups enabled.

13.11 Interrupts

The GPIO module does not generate interrupts.

Chapter 14
JTAG Port

14.1 Introduction

This chapter describes the 56800E core-based family of chips, providing board and chip-level debugging and high-density circuit board testing specific to Joint Test Action Group (JTAG).

The 56852 provides board and chip-level testing capability through two on-chip modules, both accessed through the JTAG port/EOnCE module interface:

- Enhanced On-chip Emulation (EOnCE) module
- Test Access Port (TAP) and 16-state controller, also known as the JTAG port

Presence of the JTAG port/EOnCE module interface permits insertion of the device into a target system while retaining debug control. This capability is especially important for devices without an external bus, because it eliminates the need for an expensive cable to bring out the chip footprint required by a traditional emulator system.

The Enhanced OnCE (EOnCE) module is used in Digital Signal Controller (DSC) chips to debug application software employed with the chip. The port is a separate, on-chip block, allowing non-intrusive interaction with accessibility through the pins of the JTAG interface. The EOnCE module makes it possible to examine registers, memory, or on-chip peripherals' contents in a special debug environment. This avoids sacrificing any user-accessible, on-chip resources to perform debugging procedures. Please refer to the 56F800E Core-Based Reference Manual *(DSP56800ERM)* for details about implementation of the 56852 EOnCE module.

The JTAG port is a dedicated user-accessible TAP compatible with the *IEEE 1149.1a-1993 Standard Test Access Port and Boundary Scan Architecture*. Problems associated with testing high-density circuit boards have led to the development of this proposed standard under the sponsorship of the Test Technology Committee of IEEE and the JTAG. 56852 supports circuit board test strategies based on this standard.

Six dedicated pins interface to the TAP containing a 16-state controller. The TAP uses a boundary scan technique to test the interconnections between integrated circuits after they are assembled onto a Printed Circuit Board (PCB). Boundary scans allow observation and control signal levels at each component pin through a Shift Register placed next to each pin. This is important for testing continuity and determining if pins are stuck at a one or zero level.

14.2 Features

Features of the Test Access Port (TAP) port include:

- Perform boundary scan operations to test circuit board electrical continuity
- Bypass the TAP for a given circuit board test by replacing the Boundary Scan Register (BSR) with a single-bit register
- Sample system pins during operation and transparently shift-out the results in the BSR
- Preload output pins prior to invoking the EXTEST instruction
- Disable the output drive to pins during circuit board testing
- Provide a means of accessing the EOnCE module controller and circuits to control a target system
- Query the IDCODE from any TAP in the system
- Force test data onto the peripheral outputs while replacing its BSR with a single bit register
- Enable/disable pull-up devices on peripheral boundary scan pins

14.3 Master Test Access Port (TAP)

The Master TAP consists of:

- Synchronous finite 16-bit state machine
- Eight-bit Instruction Register (IR)
- Chip Identification Register (CID)
- Bypass Register (BYPASS)
- Boundary Scan Register (BSR).

Please see **Table 14-1** for additional information.

14.3.1 Signal Description

As described in IEEE 1149.1a, the JTAG port requires a minimum of four pins to support TDI, TDO, TCK, and TMS signals. The 56852 also uses the optional $\overline{\text{TRST}}$ input signal and the $\overline{\text{DE}}$ output signal used by the EOnCE module interface. Pin functions are described in **Table 14-1.**

Table 14-1. JTAG Pin Descriptions

Pin Name	Pin Description
TDI	**Test Data Input**—This input pin provides a serial input data stream to the JTAG and the EOnCE modules. It is sampled on the rising edge of TCK and has an on-chip pull-up resistor.
TDO	**Test Data Output**—This tri-state output pin provides a serial output data stream from the JTAG and the EOnCE modules. It is driven in the Shift-IR and Shift-DR controller states of the JTAG state machine and changes on the falling edge of TCK.
TCK	**Test Clock Input**—This input pin provides a gated clock to synchronize the test logic and shift serial data to and from the JTAG/EOnCE port. If the EOnCE module is not being accessed, the maximum TCK frequency is 1/4 the maximum frequency for the 56800E core. When accessing the EOnCE module through the JTAG TAP, the maximum frequency for TCK is 1/8 the maximum frequency specified for the 56800E core. The TCK pin has an on-chip pull-down resistor.
TMS	**Test Mode Select Input**—This input pin is used to sequence the JTAG TAP Controller's state machine. It is sampled on the rising edge of TCK and has an on-chip pull-up resistor.
$\overline{\text{TRST}}$	**Test Reset**—This input provides a reset signal to the JTAG TAP Controller. The $\overline{\text{TRST}}$ pin has an on-chip pull-up resistor.
$\overline{\text{DE}}$	**Debug Event**—This bidirectional signal debugs events detected on a trigger condition.

14.4 TAP Block Diagram

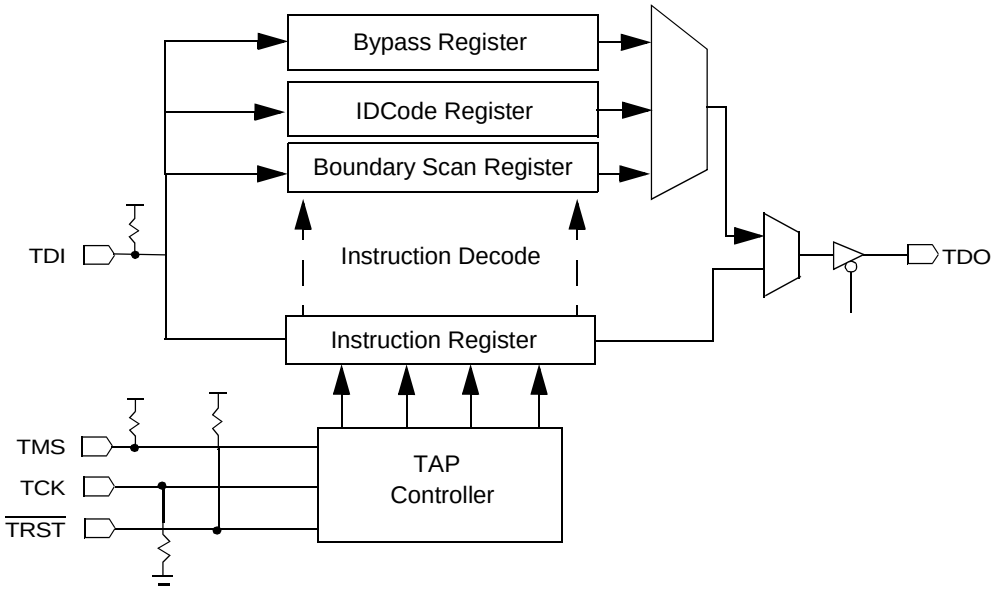


Figure 14-1. Test Access Port (TAP) Block Diagram

14.5 JTAG Port Architecture

The TAP Controller is a simple state machine used to sequence the JTAG port through its varied operations:

- Serially shift in or out a JTAG port command
- Update and decode the JTAG port Instruction Register (JTAGIR)
- Serially input or output a data value
- Update a JTAG port or EOnCE module register

Note: The JTAG port supervises the shifting of data into and out of the EOnCE module through TDI and TDO pins respectively. In this case, the shifting is guided by the same controller used when shifting JTAG information.

The JTAG block diagram is illustrated in **Figure 14-1.** The JTAG port has four read/write registers:

1. Instruction Register (JTAGIR)
2. Chip Identification Register (CID)
3. Bypass Register (JTAGBR)
4. Boundary Scan Register (BSR)

Access to the EOnCE registers is described in the 56800E Reference Manual (*DSP56800ERM*).

14.5.1 JTAG Instruction Register (JTAGIR) and Decoder

The TAP Controller contains an 8-bit instruction register. The instruction is presented to an instruction decoder during the update-instruction register state. Please see **Section 14.8** for a description of the TAP Controller operating states. The instruction decoder interprets and executes the instructions according to the conditions defined by the TAP Controller state machine.

The 56852 includes the three mandatory public instructions:

1. BYPASS
2. SAMPLE/PRELOAD
3. EXTEST

The 56852 includes four public instructions:

1. CLAMP
2. HIGH-Z
3. IDCODE
4. TLM_SELECT

The eight bits B[7:0] of the IR, decode the nine instructions, illustrated in **Figure 14-2** and its data provided in **Table 14-2.** All other encodings are reserved.

IR	7	6	5	4	3	2	1	0‘
Read/Write	B7	B6	B5	B4	B3	B2	B1	B0
Reset	0	0	0	0	0	0	1	0

Figure 14-2. JTAGIR Register

CAUTION

Reserved JTAG instruction encodings should not be used. Hazardous operation of the chip could occur if these instructions are used.

Table 14-2. Master TAP Instructions Opcode

Instruction	Target Register	Opcode
EXTEST	Boundary	00000000
BYPASS	Bypass	11111111
SAMPLE_PRELOAD	Boundary	00000001
IDCODE	IDCode	00000010
TLM_SEL	TLM	00000101
HIGH-Z	Bypass	00000110
CLAMP	Bypass	00000111
Reserved	Reserved	00000011
Reserved	Reserved	00000100
Reserved	Reserved	00001000

14.5.1.1 External Test Instruction (EXTEST)

The External Test (EXTEST) instruction enables the BSR between TDI and TDO, including cells for all digital device signals and associated control signals. The EXTAL, $\overline{\text{RESET}}$ pins, and any codec pins associated with analog signals, are not included in the BSR path.

In EXTEST, the BSR is capable of scanning user-defined values onto output pins, capturing values presented to input signals and controlling the direction and value of bidirectional pins. EXTEST instruction asserts internal system reset for the controller system logic during its run in order to force a predictable internal state while performing external boundary scan operations.

14.5.1.2 Bypass Instruction (BYPASS)

The BYPASS instruction enables the single-bit bypass register between TDI and TDO, illustrated in **Figure 14-3.** This creates a Shift Register path from TDI to the bypass register and finally to TDO, circumventing the BSR. This instruction is used to enhance test efficiency by shortening the overall path between TDI and TDO when no test operation of a component is required. In this instruction, the controller system logic is independent of the TAP. When this instruction is selected, the test logic has no effect on the operation of the on-chip system logic, required in IEEE 1149.1-1993a.

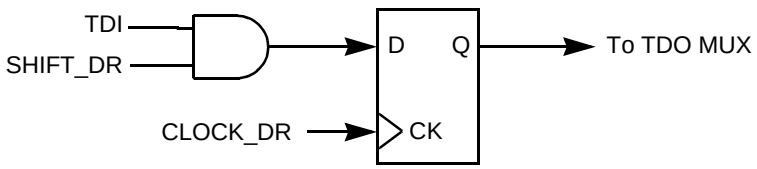


Figure 14-3. Bypass Register

14.5.2 Sample and Preload Instructions (SAMPLE/PRELOAD)

The SAMPLE/PRELOAD instruction enables the BSR between TDI and TDO. When this instruction is selected, the test logic operation has no effect on the operation of the on-chip system logic. Nor does it have an effect on the flow of a signal between the system pin and the on-chip system logic, specified by IEEE 1149.1-1993a. This instruction provides two separate functions.

1. First, it provides a means to obtain a snapshot of system data and control signals (SAMPLE). The snapshot occurs on the rising edge of TCK in the Capture-DR controller state. The data can be observed by shifting it transparently through the BSR.

   In a normal system configuration, many signals require external pull-ups assuring proper system operation. Consequently, the same is true for the SAMPLE/PRELOAD functionality. Data latched into the BSR during the Capture-DR controller state may not match the drive state of the package signal if the system requiring pull-ups are not present within the test environment.

2. The second function of the SAMPLE/PRELOAD instruction is to initialize the BSR output cells (PRELOAD) prior to selection of the CLAMP or EXTEST instruction. This initialization ensures known data appears on the outputs when executing EXTEST. The data held in the Shift Register stage is transferred to the output latch on the falling edge of TCK in the update Data Register (DR) controller state. Data is not presented to the pins until the CLAMP or EXTEST instruction is executed.

Note: Since there is no internal synchronization between the JTAG clock (TCK) and the system Clock (CLK), some form of external synchronization to achieve meaningful results when sampling system values using the SAMPLE/PRELOAD instruction must be provided.

14.5.2.1 Identification Code Instruction (IDCODE)

The IDCODE instruction enables the IDREGISTER between TDI and TDO. It is provided as a public instruction to allow the manufacturer part number and version of a component to be determined through the TAP.

14.5.2.2 TAP Linking Module Select Instruction (TLM_SEL)

TLM_SEL instruction is a user-defined JTAG instruction. It is used to disable the Master TAP and enable the TAP Linking Module (TLM). The TLM provides a means of connecting one or more TAPs in a multi-TAP design, responding to the IC’s test pins in IEEE 1149.1 scan operations. TLM serves as a community data register used to set the TAP linking configuration

desired. The TLM Register is a 4-bit register, illustrated in **Table 14-3,** and enabled between TDI and TDO during a shift Data Register (DR) operation. It is updated on the Update DR operation.

Table 14-3. TLM Register

Update DR (Load)	Shift DR (Capture)	Bit
Master TAP	N/A	0
56800E TAP	N/A	1
N/C	N/A	2
N/C	N/A	3

14.5.2.3 High-Z Instruction (HIGHZ)

The HIGHZ instruction enables the single-bit bypass register between TDI and TDO. It is provided as a public instruction in order to prevent having to drive the output signals back during circuit board testing. When the HIGHZ instruction is invoked, all output drivers are placed in an inactive-drive state. HIGHZ asserts internal system reset for the controller system logic for the duration of HIGHZ in order to force a predictable internal state while performing external boundary scan operations.

14.5.3 JTAG Chip Identification (CID) Register

The Chip Identification (CID) register is a 32-bit register providing a unique JTAG ID for the 56852. It is offered as a public instruction to allow the manufacturer, part number, and version of a component to be determined through the TAP. **Figure 14-4** illustrates the CID register configuration.

CIR = $2	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	PNUM 3	PNUM 2	PNUM 1	PNUM 0	MFG ID 11	MFG ID 10	MFG ID 9	MFG ID 8	MFG ID 7	MFG ID 6	MFG ID 5	MFG ID 4	MFG ID 3	MFG ID 2	MFG ID 1	MFG ID 0
Write																
Reset	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	1

CIR = $2	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Read	VER 3	VER 2	VER 1	VER 0	PNUM 15	PNUM 14	PNUM 13	PNUM 12	PNUM 11	PNUM 10	PNUM 9	PNUM 8	PNUM 7	PNUM 6	PNUM 5	PNUM 4
Write																
Reset	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	1

Figure 14-4. JTAG Chip Identification (CID) Register

The device identification number for the initial release of the 56852 is $01F5401D.

Table 14-4. Device ID Register Bit Assignment

Bit No.	Code Use	56852 Values
31–28	Version Number	0000 (For initial version only—these bits may vary)
27–22	Freescale Design Center ID	00 0111
21–12	Family and part ID	11 0101 0100
11-1	Freescale Manufacturer ID	000 0000 1110
0	IEEE Requirement	Always 1

14.6 JTAG Bypass Register (JTAGBR)

The JTAG bypass register is a one-bit register used to provide a simple, direct path from the TDI pin to the TDO pin. This is useful in boundary scan applications where many chips are serially connected in a daisy-chain. Individual DSCs, or other devices, can be programmed with the BYPASS instruction so individually they become pass-through devices during testing. This allows testing of a specific chip, while still having all of the chips connected through the JTAG ports.

IR = $6, $7, $FF	
Read/Write	
Reset	0

Figure 14-5. JTAG Bypass Register (JTAGBR)

14.7 JTAG Boundary Scan Register (BSR)

The JTAG Boundary Scan Register (BSR) is configured as described in **Figure 14-6.** This register is enabled via the JTAG Master TAP by issuing the EXTEST, or SAMPLE_PRELOAD instructions enabling the boundary scan registers between TDI and TDO. Boundary Scan Register cell number one is connected to TDO making it the first data bit shifted into TDI. It is the first bit shifted out of TDO when loading and unloading the boundary scan chain. For the most current BSDL files, please refer to *www.freescale.com*. **Figure 14-6** illustrates the register, while **Table 14-5** provides the contents of the BSR for the 56852.

IR = $0, $1, $3	337	336	335	334	333	Bits 332 through 5						4	3	2	1	0
Read-Only																

Figure 14-6. Boundary Scan Register (BSR)

Table 14-5. BSR Contents for 56852

Bit Number	Pin/Bit Name	Pin Type	BSR Cell	Pin Number
0	$\overline{\text{IRQA}}$	Input	BC_1	A1
1		Pull-up	BC_1	
2	$\overline{\text{IRQB}}$	Input	BC_1	C2
3		Pull-up	BC_1	
4	$\overline{\text{CS0}}$	Input/Output	BC_7	D2
5		Pull-up	BC_1	
6		Enable	BC_2a	
7	$\overline{\text{CS1}}$	Input/Output	BC_7	D3
8		Pull-up	BC_1	
9		Enable	BC_2a	
10	$\overline{\text{CS2}}$	Input/Output	BC_7	C3
11		Pull-up	BC_1	
12		Enable	BC_2a	
13	$\overline{\text{RD}}$	Input/Output	BC_7	E2
14		Pull-up	BC_1	
15		Enable	BC_2a	
16	$\overline{\text{WR}}$	Input/Output	BC_7	E3
17		Pull-up	BC_1	
18		Enable	BC_2a	
19	A0	Input/Output	BC_7	E4
20		Pull-up	BC_1	
21		Enable	BC_2a	
22	A1	Input/Output	BC_7	F2
23		Pull-up	BC_1	
24		Enable	BC_2a	
25	A2	Input/Output	BC_7	F3
26		Pull-up	BC_1	
27		Enable	BC_2a	
28	A3	Input/Output	BC_7	F4
29		Pull-up	BC_1	
30		Enable	BC_2a	
31	A4	Input/Output	BC_7	F1
32		Pull-up	BC_1	
33		Enable	BC_2a	
34	A5	Input/Output	BC_7	G3
35		Pull-up	BC_1	
36		Enable	BC_2a	

Table 14-5. BSR Contents for 56852 (Continued)

Bit Number	Pin/Bit Name	Pin Type	BSR Cell	Pin Number
37	A6	Input/Output	BC_7	G2
38		Pull-up	BC_1	
39		Enable	BC_2a	
40	A7	Input/Output	BC_7	J1
41		Pull-up	BC_1	
42		Enable	BC_2a	
43	A8	Input/Output	BC_7	H2
44		Pull-up	BC_1	
45		Enable	BC_2a	
46	A9	Input/Output	BC_7	H3
47		Pull-up	BC_1	
48		Enable	BC_2a	
49	A10	Input/Output	BC_7	J2
50		Pull-up	BC_1	
51		Enable	BC_2a	
52	A11	Input/Output	BC_7	H4
53		Pull-up	BC_1	
54		Enable	BC_2a	
55	A12	Input/Output	BC_7	G4
56		Pull-up	BC_1	
57		Enable	BC_2a	
58	A13	Input/Output	BC_7	J3
59		Pull-up	BC_1	
60		Enable	BC_2a	
61	A14	Input/Output	BC_7	F5
62		Pull-up	BC_1	
63		Enable	BC_2a	
64	A15	Input/Output	BC_7	H5
65		Pull-up	BC_1	
66		Enable	BC_2a	
67	A16	Input/Output	BC_7	E5
68		Pull-up	BC_1	
69		Enable	BC_2a	
70	A17	Input/Output	BC_7	F6
71		Pull-up	BC_1	
72		Enable	BC_2a	
73	A18	Input/Output	BC_7	G5
74		Pull-up	BC_1	
75		Enable	BC_2a	

Table 14-5. BSR Contents for 56852 (Continued)

Bit Number	Pin/Bit Name	Pin Type	BSR Cell	Pin Number
76	A19	Input/Output	BC_7	B8
77		Pull-up	BC_1	
78		Enable	BC_2a	
79	A20 (CLK0)	Input/Output	BC_7	J8
80		Pull-up	BC_1	
81		Enable	BC_2a	
82	D0	Input/Output	BC_7	G7
83		Pull-up	BC_1	
84		Enable	BC_2a	
85	D1	Input/Output	BC_7	H7
86		Pull-up	BC_1	
87		Enable	BC_2a	
88	D2	Input/Output	BC_7	H8
89		Pull-up	BC_1	
90		Enable	BC_2a	
91	D3	Input/Output	BC_7	G8
92		Pull-up	BC_1	
93		Enable	BC_2a	
94	D4	Input/Output	BC_7	H9
95		Pull-up	BC_1	
96		Enable	BC_2a	
97	D5	Input/Output	BC_7	E8
98		Pull-up	BC_1	
99		Enable	BC_2a	
100	D6	Input/Output	BC_7	F7
101		Pull-up	BC_1	
102		Enable	BC_2a	
103	D7	Input/Output	BC_7	G6
104		Pull-up	BC_1	
105		Enable	BC_2a	
106	D8	Input/Output	BC_7	E8
107		Pull-up	BC_1	
108		Enable	BC_2a	
109	D9	Input/Output	BC_7	E7
110		Pull-up	BC_1	
111		Enable	BC_2a	
112	D10	Input/Output	BC_7	E6
113		Pull-up	BC_1	
114		Enable	BC_2a	

Table 14-5. BSR Contents for 56852 (Continued)

Bit Number	Pin/Bit Name	Pin Type	BSR Cell	Pin Number
115	D11	Input/Output	BC_7	D8
116		Pull-up	BC_1	
117		Enable	BC_2a	
118	D12	Input/Output	BC_7	D7
119		Pull-up	BC_1	
120		Enable	BC_2a	
121	D13	Input/Output	BC_7	D9
122		Pull-up	BC_1	
123		Enable	BC_2a	
124	D14	Input/Output	BC_7	C8
125		Pull-up	BC_1	
126		Enable	BC_2a	
127	D15	Input/Output	BC_7	A9
128		Pull-up	BC_1	
129		Enable	BC_2a	
130	$\overline{DE}$	Input/Output	BC_7	B8
131		Pull-up	BC_1	
132		Enable	BC_2a	
133	TXD	Input/Output	BC_7	D4
134		Pull-up	BC_1	
135		Enable	BC_2a	
136	RXD	Input/Output	BC_7	B4
137		Pull-up	BC_1	
138		Enable	BC_2a	
139	MOSI	Input/Output	BC_7	C5
140		Pull-up	BC_1	
141		Enable	BC_2a	
142	MISO	Input/Output	BC_7	C4
143		Pull-up	BC_1	
144		Enable	BC_2a	
145	$\overline{SS}$	Input/Output	BC_7	B3
146		Pull-up	BC_1	
147		Enable	BC_2a	
148	SCK	Input/Output	BC_7	A3
149		Pull-up	BC_1	
150		Enable	BC_2a	
151	SRXD (GPIOC1)	Input/Output	BC_7	A2
152		Pull-up	BC_1	
153		Enable	BC_2a	
154	STXD (GPIOC0)	Input/Output	BC_7	B2
155		Pull-up	BC_1	
156		Enable	BC_2a	

14.8 TAP Controller

The TAP Controller is a synchronous 16-bit finite state machine illustrated in **Figure 14-7.** It responds to changes at the TMS and TCK pins. Transitions from one state to another will occur on the rising edge of TCK. The value shown adjacent to each state transition represents the signal present on TMS at the time of a rising edge of TCK.

The TDO pin will remain in the *high* impedance state except during the Shift-DR and Shift-IR TAP Controller states. In these controller states, TDO will update on the falling edge of TCK. TDI is sampled on the rising edge of TCK.

The TAP Controller will execute the last instruction decoded until a new instruction is entered at the Update-IR state, or Test-Logic-Reset is entered.

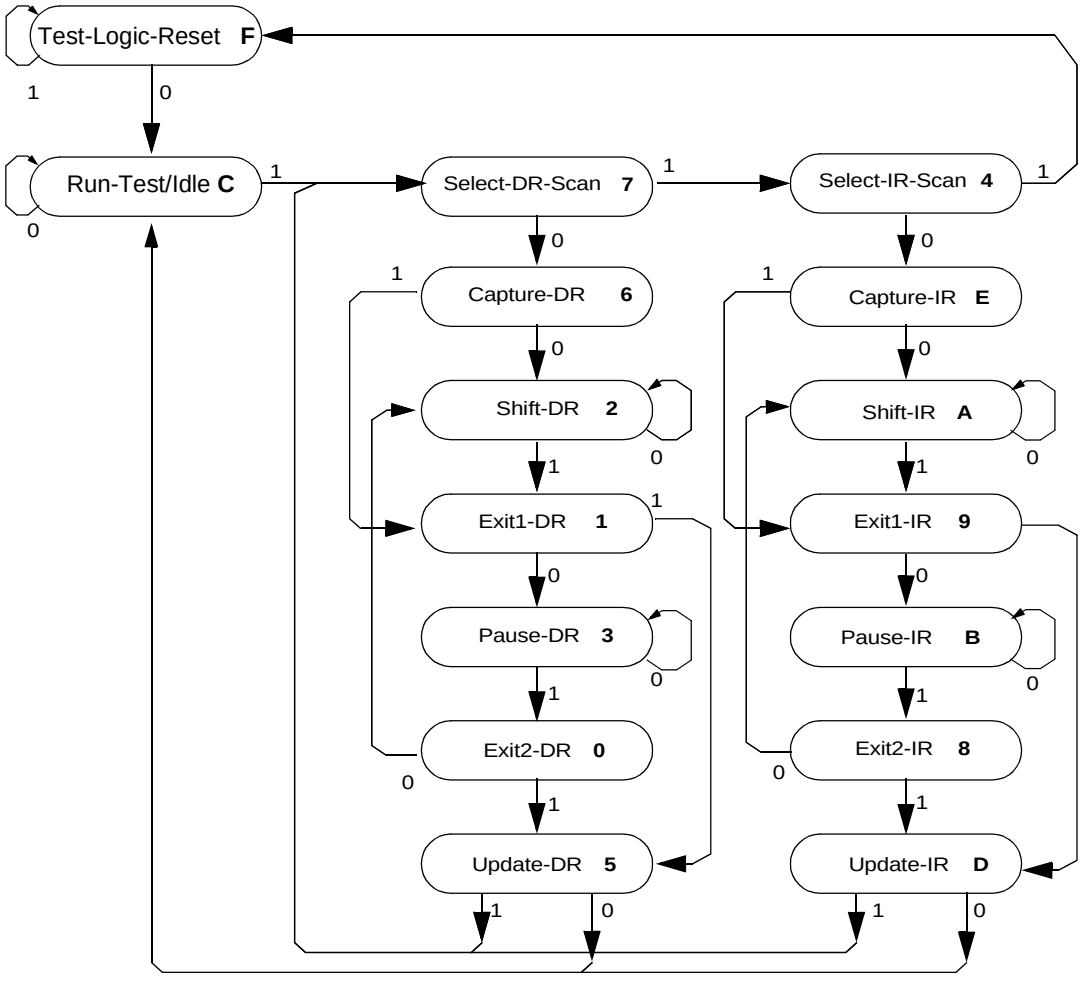


Figure 14-7. TAP Controller State Diagram

The TAP Controller will execute the last instruction decoded until a new instruction is entered at the Update-IR state, or Test-Logic-Reset is entered.

There are two paths through the 16-state machine. The shift-IR-scan path captures and loads JTAG instructions into the JTAGIR. The shift-DR-scan path captures and loads data into the other JTAG registers. The TAP Controller executes the last instruction decoded until a new instruction is entered at the update-IR state, or until the test-logic-reset state is entered. When using the JTAG port to access EOnCE module registers, follow these four steps:

1. Enable the TLM by shifting the TLM_SEL instruction into the JTAGIR.
2. When selected, the TLM must enable the 56800E TAP by shifting in the appropriate value into the TLM Register.
3. When the 56800E TAP is selected, the EOnCE module is selected by shifting the ENABLE_EOnCE instruction.
4. The EOnCE module registers and commands are read and written through the JTAG pins using the shift-DR-scan path.

Asserting the JTAG's $\overline{\text{TRST}}$ pin asynchronously forces the JTAG state machine into the test-logic-reset state.

14.8.1 Operation

All state transitions of the TAP Controller occur based on the value of TMS at the time of a rising edge of TCK. Actions of the instructions occur on the falling edge of TCK in each controller state illustrated in **Figure 14-7.**

14.8.1.1 Test Logic Reset (pstate = F)

During Test-Logic-Reset all JTAG test logic is disabled so the chip can operate in a normal mode. This is achieved by initializing the Instruction Register (IR) with the IDCODE instruction. By holding TMS *high* for five rising edges of TCK, the device will always remain in Test-Logic-Reset no matter what state the TAP Controller was in previously.

14.8.1.2 Run-Test-Idle (pstate = C)

Run-Test-Idle is a controller state between scan operations. EOnCE entered, the controller will remain in the Run-Test-Idle mode as long as TMS is held *low*. When TMS is *high* and a rising edge of TCK occurs, the controller moves to the Select-DR state.

14.8.1.3 Select Data Register (pstate = 7)

The Select-DR state is a temporary state. In this state, all Test Data Registers selected by the current instruction retains their previous states. If TMS is held *low* and a rising edge of TCK occurs when the controller is in this state, the controller moves into the Capture-DR state and a scan sequence for the selected Test Data Register is initiated. If TMS is held *high* and a rising edge of TCK occurs, the controller moves to the Select-IR state.

14.8.1.4 Select Instruction Register (pstate = 4)

The Select-IR state is a temporary state. In this state, all Test Data Registers selected by a current instruction retain their previous states. If TMS is held *low* and a rising edge of TCK occurs when the controller is in this state, the controller moves into the Capture-IR state and a scan sequence for the Instruction Register is initiated. If TMS is held *high* and a rising edge of TCK occurs, the controller moves to the Test-Logic-Reset state.

14.8.1.5 Capture Data Register (pstate = 6)

In this controller state, data may be parallel loaded into test registers selected by the current instruction on the rising edge of TCK. If a test data register selected by the current instruction does not have a parallel input, the register retains its previous value.

14.8.1.6 Shift Data Register (pstate = 2)

In this controller state, the Test Data Register is connected between TDI and TDO. This data is then shifted one stage towards its serial output on each rising edge of TCK. The TAP Controller will remain in this state while TMS is held at a *low*. When a one is applied to TMS and a positive edge of TCK occurs, the controller will move to the Exit1-DR state.

14.8.1.7 Exit1 Data Register (pstate = 1)

This is a temporary controller state. If TMS is held *high*, and a rising edge is applied to TCK while in this state, it causes the controller to advance to the Update-DR state. This terminates the scanning process.

14.8.1.8 Pause Data Register (pstate = 3)

This controller state allows shifting of the Test Data Register in the serial path between TDI and TDO to be temporarily halted. All test data registers selected by the current instruction retain their previous state unchanged. The controller remains in this state while TMS is held *low*. When TMS goes *high* and a rising edge is applied to TCK, the controller advances to the Exit2-DR state.

14.8.1.9 Exit2 Data Register (pstate = 0)

This is a temporary controller state. If TMS is held *high*, and a rising edge is applied to TCK while it is in this state, the scanning process terminates and the TAP Controller advances to the Update-DR state. If TMS is held *low* and a rising edge of TCK occurs, the controller advances to the Shift-DR state.

14.8.1.10 Update Data Register (pstate = 5)

All boundary scan registers contain a two stage data register. It isolates the shifting and capturing of data on the peripheral from what is applied to internal logic during scan mode. This register is the second stage, or parallel output, and it is used to apply a stimulus to internal logic. Data is latched on the parallel output of these Test Data Registers from the Shift Register path on the falling edge of TCK in the Update-DR state. On a rising edge of TCK, the controller advances to the Select_DR state if TMS is held *high* or the Run-Test-Idle state If TMS is held *low*.

14.8.1.11 Capture Instruction Register (pstate = E)

When the TAP Controller is in this state and a rising edge of TCK occurs, the controller advances to the Exit1-IR state if TMS is held at a one or the Shift-IR state if TMS is held at a zero.

14.8.1.12 Shift Instruction Register (pstate = A)

In this controller state, the Shift Register contained in the Instruction Register (IR) is connected between TDI and TDO and shifts data one stage towards it’s serial output on each rising edge of TCK. When the TAP Controller is in this state and a rising edge of TCK occurs, the controller advances to the Exit1-IR state if TMS is held at a one or remains in the Shift-IR state if TMS is held at a zero.

14.8.1.13 Exit1 Instruction Register (pstate = 9)

This is a temporary controller state. If TMS is held *high*, and a rising edge is applied to TCK while in this state causes the controller to advance to the Update-IR state. This terminates the scanning process. If TMS is held *low* and a rising edge of TCK occurs the controller advances to the Pause-IR state.

14.8.1.14 Pause Instruction Register (pstate = B)

This controller state allows shifting of the Instruction Register (IR) in the serial path between TDI and TDO to be temporarily halted. All Test Data Registers selected by the current instruction retain their previous state unchanged. The controller remains in this state while TMS is held *low*. When TMS goes *high* and a rising edge is applied to TCK, the controller advances to the Exit2-IR state.

14.8.1.15 Exit2 Instruction Register (pstate = 8)

This is a temporary controller state. If TMS is held *high*, and a rising edge is applied to TCK while in this state, the scanning process terminates and the TAP Controller advances to the Update-IR state. If TMS is held *low* and a rising edge of TCK occurs, the controller advances to the Shift-IR state.

14.8.1.16 Update Instruction Register (pstate = D)

During this state, instruction shifted into the Instruction Register (IR) is latched from the Shift Register path on the falling edge of TCK and into the instruction latch. It becomes the current instruction. On a rising edge of TCK, the controller advances to the Select_IR state if TMS is held *high* or the Run-Test-Idle state If TMS is held *low*.

14.9 56852 Restrictions

The control afforded by the output enable signals using the BSR and the EXTEST instruction requires a compatible circuit board test environment to avoid any device-destructive configurations. *Avoid situations when the 56852 output drivers are enabled into actively driven networks.*

During power-up, the $\overline{\text{TRST}}$ pin must be externally asserted to force the TAP Controller into this state. After power-up is concluded, TMS must be sampled as a Logic 1 for five consecutive TCK rising edges. If TMS either remains unconnected or is connected to V_{DD}, then the TAP Controller cannot leave the test-logic-reset state, regardless of the state of TCK.

56852 features a low-power Stop mode invoked using the stop instruction. JTAG interaction with low-power Stop mode is as follows:

1. The TAP Controller must be in the test-logic-reset state to either enter or remain in Stop mode. Leaving the TAP Controller test-logic-reset state negates the ability to achieve low-power, but does not otherwise affect device functionality.
2. The TCK input is not blocked in low-power Stop mode. To consume minimal power, the TCK input should be tied to ground only.
3. The TMS and TDI pins include On-Chip Pull-Up resistors. In low-power Stop mode, these two pins should remain either unconnected or connected to V_{DD} to achieve minimal power consumption.

Because all 56852 clocks are disabled during Stop state, the JTAG interface provides the means of polling the device status, sampled in the Capture-IR state.

Appendix A
Glossary

A.1 Glossary

This glossary is intended to reduce confusion potentially caused by the use of many acronyms and abbreviations throughout this manual.

ACIM	A/C Induction Motors
A/D	Analog-to-Digital
ADC	Analog to Digital Converter
ADCR	ADC Control Registe
ADDR	Address
ADHLMT	ADC High Limit Registers
ADLLMT	ADC Low Limit Registers
ADLST	ADC Channel List Registers
ADLSTAT	ADC Limit Status Register
ADM	Application Development Module
ADOFS	ADC Offset Registers
ADR PD	Address Bus Pull-up Disable
ADRSLT	ADC Result Registers
ADSDIS	ADC Sample Disable Register
ADSTAT	ADC Status Register
ADZCC	ADC Zero Crossing Control Register
ADZCSTAT	ADC Zero Crossing Status Register
AGU	Address Generation Unit
ALU	Arithmetic Logic Unit
API	Application Program Interface
Barrel Shifter	Part of the ALU that allows single cycle shifting and rotating of data word
BCR	Bus Control Register
BDC	Brush DC Motor
BE	Breakpoint Enable
BFIU	Boot Flash Interface Unit
BFLASH	Boot Flash
BK	Breakpoint Configuration Bit
BLDC	Brushless DC Motor
BLKSZ	Base Address and Block Size Register in the EMI peripherial

BOTNEG	Bottom-side PWM Polarity Bit
BS	Breakpoint Selection
BSDL	Boundary Scan Description Language
BSR	Boundary Scan Register
CAN	Controller Area Network
CC	Condition Codes
CAP	Capture
CDBR	Core Data Bus Read
CDBW	Core Data Bus Write
CEN	COP Enable Bit
CFG	Config
CGDB	Core Global Data Bus
CGM	Clock Generator Module
CGMDB	Clock Generator Module Divide-By Register in the OCCS Module
CGMTOD	Clock Generator Module Time of Day Register in the OCCS Module
CGMTST	Clock Generator Module Test Register in the OCCS Module
CHCNF	Channel Configure
CID	Chip Identification Register
CKDIVISOR	Clock Divisor
CLKO	Clock Output pin
CLKOSEL	CLKO Select
CLKOSR	Clock Select Register
CMOS	Complementary metal oxide semiconductor. (A form of digital logic that is characterized by low power consumption, wide power suppply range, and high noise immunity.)
CMP	Compare
CNT	Count
CNTR	Counter
Codec	Coder/Decoder
COP	Computer Operating Properly
COP/RTI	Computer Operating Properly/Real Time Interface
COPCTL	COP Control
COPDIS	COP Timer Disable
COPR	COP Reset

COPSRV	COP Service
COPTO	COP Time Out
CP	Charge Pump
CPHA	Clock Phase
CPOL	Clock Polarity
CPU	Central Processing Unit
CRC	Cyclic Redundancy Code
CS	Chip Select
CSEN	Cop Stop Enable
CSOR	Chip Select Option Register in the EMI peripheral
CTRL	Control
CTRL PD	Control signal Pull-up Disable
CVR	Command Vector Regsiter
CWEN	COP Wait Enable Bit
CWP	COP Write Protect
DAC	Digital to Analog Converter
DAT	Data/Address Select
DATA ALU	Data Address Limit
DATA PD	Data bus I/O Pull-up Disable
DC	Down Counter programmable divide by *n* counter
DDA	Analog Power
DDR	Data Direction Register
DEC	Quadrature Decoder Module
DEE	Dumb Erase Enable
DFIU	Data Flash Interface Unit
DFLASH	Data Flash
DIE	Watchdog Time-Out Interrupt Enable
DIRQ	Watchdog Time-Out Interrupt Request
DM	Data Memory
DMA	Direct Memory Access
DMADR	Data Memory Address
DMW	Data Memory Write

DPE	Dumb Programming Enable
DR	Data Register
DRV	Drive Control Bit
DSC	Digital Signal Controller
DSO	Data Shift Order
DSP	Digital Signal Processor
EDG	Edge-Aligned or Center-Aligned PWMs
EE	Erase Enable
EEOF	Enable External OFLAG Force
EM	Event Modifier
EMI	External Memory Interface
EN	Enable3
ENA	Enables (TAP TLM)
ENCR	Encoder Control Register
EOSI	End of Scan Interrupt
EOSIE	End of Scan Interrupt Enable
ERASE	Erase Cycle
ERRIE	Error Interrupt Enable
EX	External X Memory
EXTBOOT	External Boot
EXTR	External Reset
FAULT	Fault Input to PWM
FE	Framing Error Flag
FLAGx	FAULTx Pin Flag
FH	FIFO Halt
FIEx	Faultx Pin Interrupt Enable
FSM	Finite State Machine
FIR	Filter Interval Register
FLOCI	Force Loss of Clock
FLOLI	Force Loss of Lock
FMODEx	FAULTx Pin Clearing Mode
FOSC	Oscillator Frequency

FPINx	FAULTx Pin
FREF	Reference Frequency
FTACKx	FAULTx Pin Acknowledge
GPIO	General Purpose Input/Output
GPR	Group Priority Register
Harvard Architecture	A microprocessor architecture using separate buses for program and data. This is data is typically used on controllers to optimise the data throughput.
HACK	Host Acknowledge Input Pin
HBO	Hardware Breakpoint Occurrence
HC	Host Command Bit
HCIE	Host Command Interrupt Enable Bit
HCP	Host Command Pending Bit
HCR	Host Interface Control Register
HDDS	Host Dual Data Strobe Bit
HDMA	Host DMA Status Bit
HF0	Host Flag 0 Bit (general-purpose flag)
HF1	Host Flag 1 Bit (general-purpose flag)
HF2	Host Flag 2 Bit (general-purpose flag)
HF3	Host Flag 3 Bit (general-purpose flag)
HLEND	Host Little Endian Bit
HLMTI	High Limit Interrupt Bit
HLMTIE	High Limit Interrupt Enable Bit
HM0	Host Mode Control 0 Bit
HM1	Host Mode Control 1 Bit
HOLD	Hold Register
HOME	Home Switch Input
HRDF	Host Status Receive Data Full Bit
HREQ	Host Request Output Bit
HRIE	Host Receive Interrupt Enable Bit
HRMS	Host Request Mode Select Bit
HRRQ	Host Receive Request Bit
HRX	Host Interface Data Register

HSR	Host Interface Status Register
HTDE	Host Transmit Data Empty Bit
HTIE	Host Transmit Interrupt Enable Bit
HTRQ	Host Transmit Request Bit
HTX	Host Transmit Data Register
HV	Host Vector Bits
IA	Interrupt Assert
IC	Integrated Circuit
ICR	Interface Control Register
IE	Interrupt Enable
IEE	Intelligent Erase Enable
IEF	Input Edge Flag
IEFIE	Input Edge Flag Interrupt Enable
IENR	Interrupt Enable Register
IES	Interrupt Edge Sensitive
IFREN	Information Block Enable
IMR	Input Monitor Register
INDEP	Independent or Complimentary Pair Operation
INDEX	Index Input
INIT	Initialize Bit
INPUT	External Input Signal
INV	Invert
I/O	Input/Output
IP	Interrupt Pending
IPBus	Intellectual Properties Bus
IPE	Intelligent Program Enable
IPOL	Current Polarity
IPOLR	Interrupt Polarity Register
IPBBA	Interrupt Properties Bus Bridge Address
IPBB	Interrupt Pending Bus Bridge
IPR	Interrupt Pending Register (in GPIO)
IPR	Interrupt Priority Register (in the Core)

IPS	Input Polarity Select
IRQ	Interrupt Request
IS	Interrupt Source
ISC	In Select Control (TAP TLM)
ISR	Interface Status Register
IVR	Interrupt Vector Regsiter
ITCN	Interrupt Controller
JTAG	Joint Test Action Group
JTAGBR	JTAG Bypass Register
JTAGIR	JTAG Instruction Register
LC	Link Controls
LCD	Liquid Crystal Display
LCK	Loss of Lock
LDOK	Load OKay
LF	Loop Filter
LIR	Lower Initialization Register
LLMTI	Low Limit Interrupt
LLMTIE	Low Limit Interrupt Enable
LOAD	Load Register
LOCI	Loss of Clock
LOCIE	Los of Clock Interrupt Enable
LOLI	PLL Lock of Lock Interrupt
LOOP	Loop Select Bit
LPOS	Lower Position Counter Register
LPOSH	Lower Position Hold Register
LSB	Least Significant Bit
LSH_ID	Most Significant Half of JTAG_ID
LVD	Low Voltage Detect
LVIE	Low Voltage Interrupt Enable
LVIS	Low Voltage Interrupt Source
M	Mode
MA	Mode A

MAC	Multiply and Accumulate
MAS	Mass Cycle Erase
MB	Mode B
MCU	Microcontroller Unit
MHz	Megahertz
MIPS	Million Instructions Per Second
MISO	Master In/Slave Out
MODF	Mode Fault Error
MODFEN	Mode Fault Enable
MOSI	Master Out/Slave In
MPIO	Multi-Purpose Input/Output (A, B, C, D, E or F)
MSB	Most Significant Bit
MSH_ID	Most Significant Half of JTAG ID
MSTR	Master Mode
MUX	Multiplexer
NF	Noise Flag
NL	Nested Looping
NOR	An inversion of the logical OR function
NVSTR	Non-volatile Store Cycle Definition
OBAR	OnCE Breakpoint Address Register
OBCTL	OnCE Breakpoint Control Register
OBMSK	OnCE Breakpont Mask Register
OCMDR	OnCE Command Register
OCCS	On-Chip Clock Synthesis
OCNTR	OnCE Count Register
OCR	OnCE Control Register
ODEC	OnCE Decoder
OEN	Output Enable
OMAC	OnCE Memory Address Comparator
OMAL	OnCE Memory Address Latch
OMR	Operating Mode Register
OnCE	On-Chip Emulation (unit)

OPABDR OnCE Program Address Bus Decode Register

OPABER OnCE Program Address Bus Execute Register

OPABFR OnCE Program Address Bus Fetch Register

OPDBR OnCE Program Data Bus Register

OPFIFO OnCE PAB Change of Flow

OPGDBR OnCE Program Global Data Bus Register

OPS Output Polarity Select

OR Overrun

OSHR OnCE Shift Register

OSR OnCE Status Register

OVRF Overflow

PAB Program Address Bus

PD Permanent STOP/WAIT Disable

PDB Program Data Bus

PE Program Enable

PE Parity Enable Bit

PER Peripheral Enable Register

PF Parity Error Flag

PFD Phase Frequency Detector

PFIU Program Flash Interface Unit

PFLASH Program Flash

PGDB Peripheral Global Data Bus

PLL Phase Locked Loop Module

PLLCID PLL Clock In Divide

PLLCOD PLL Clock Out Divide

PLLDB PLL Divide-by

PLLCR PLL Control Register

PLLPDN PLL Power Down

PLLSR PLL Status Register

PLR Priority Level Register

PMCCR PWM Channel Control Register

PMCFG PWM Configuration Register

PMCNT	PWM Counter Register
PMCTL	PWM Control Register
PMDEADTM	PWM Deadtime Register
PMDISMAP	PWM Disable Mapping Registers
PMFCTL	PWM Fault Control Register
PMFSA	PWM Fault Status Acknowledge
PMOUT	PWM Output Control Register
PMPORT	PWM Port Register
POL	Polarity
POR	Power on Reset
PRAM	Program RAM
PROG	Program Cycle
PSR	Processor Status Register
PT	Parity Type
PTM	Peripheral Test Mode
PUR	Pull-up Enable Register
PWD	Power Down Mode
PWM	Pulse Width Modulator
PWMEN	PWM Enable
PWMF	PWM Reload Flag
PWMRIE	PWM Reload Interrupt Enable
PWMVAL	PWM Value Registers
QE	Quadrature Encoder
QDN	Quadrature Decoder Negative Signal
RAF	Receiver Active Flag
RAM	Random Access Memory
RDRF	Receive Data Register Full
RE	Receiver Enable
REIE	Receive Error Interrupt Enable
REV	Revolution Counter Register
REVH	Revolution Hold Register
RDMAEN	Receive DMA Enable Bit

RIDLE	Receiver Idle Line
RIE	Receiver Full Interrupt Enable
ROM	Read Only Memory
RPD	Re-programmable STOP/WAIT Disable
RREQ	Receive Request Bit
RSRC	Receiver Source Bit
RWU	Receiver Wake up
RXDF	Receive Data Register Full Bit
RXH	Receive Byte High Register
RXL	Receive Byte Low Register
SA	Saturation
Sample	A word or time-slot of data to be transferred in a frame
SBK	Send Break
SBO	Software Breakpoint Occurrence
SBR	SCI Baud Rate
SCI	Serial Communications Interface3
SCIBR	SCI Baud Rate Register
SCICR	SCI Control Register
SCIDR	SCI Data Register
SCISR	SCI Status Register
SCLK	Serial Clock
SCR	Status and Control
SD	Stop Delay
SDK	Software Development Kit
SEL	Selects (TAP TLM)
SEXT	Sign Extend
SIM	System Integration Module
SMODE	Scan Mode
SPDRR	SPI Data Receive Register
SPDSR	SPI Data Size Register
SPDTR	SPI Data Transmit Register
SP	SPI Enable

SPI	Serial Peripheral Interface
SPMSTR	SPI Master
SPRF	SPI Receiver Full
SPRIE	SPI Receiver Interrupt Enable
SPSCR	SPI Status Control Register
SPTE	SPI Transmitter Empty
SPTIE	SPI Transmit Interrupt Enable
SR	Status Register
SRM	Switched Reluctance Motor
$\overline{\textbf{SS}}$	Slave Select
SSI	Synchronous Serial Interface
SWAI	Stop in Wait Mode
SYS_CNTL	System Control Register
SYS_STS	System Status Register
TAP	Test Access Port
TCSR	Text Control and Status Register
TCE	Test Counter Enable
TCF	Timer Compare Flag
TCFIE	Timer Compare Flag Interrupt Enable
TCK	TAP Clock
TDI	TAP Data In
TDO	TAP Data Out
TDMAEN	Transmit DMA Enable Bit
TDRE	Transmit Date Register Empty
TE	Transmitter Enable
TEIE	Transmitter Empty Interrupt Enable
TEN	Test Mode Enable
TERASEL	Terase Limit
TESTR	Test Register
TFDBK	Test Feedback Clock
TFREF	Test Reference Frequency Clock
TIDLE	Transmitter Idle

TIIE	Transmitter Idle Interrupt Enable
Time-Slot	A frame divided into time-slots, allowing for the transfer of a word of data
TIRQ	Test Interrupt Request Register
TISR	Test Interrupt Source Register
TM	Test Mode bit
TMEL	Time Limit
TMODE	Test Mode bit
TMR	Quadrature Timer
TMR PD	Timer I/O Pull-up Disable
TNVHL	TNVH Limit
TNVSL	TNVS Limit
TO	Trace Occurrence
TOD	Time of Day Module
TOF	Timer Overflow Flag
TOFIE	Timer Oerflow Flag Interrupt Enable
TOPNEG	Top-side PWM Polarity Bit
TPROGL	Tprog Limit
TPGSL	TPGS Limit
TRCVL	TRCV Limit
TRDY	Transmit Ready Flag Bit
TREQ	Transmit Reuest Enable Bit
TSTREG	Test Register
TXDE	Transmit Data Register Empty Bit
UIR	Upper Initialization Register
UPOS	Upper Position Hold Register
UPOSH	Upper Position Hold Register
VAB	Vector Address Bus
VBA	Vector Base Address are pins on the 56800E core
VCO	Voltage Controlled Oscillator
V_{DD}	Power
V_{DDA}	Analog Power
VEL	Velocity Counter Register

VELH	Velocity Hold Register
VLMODE	Value Register Load Mode
VREF	Voltage Reference
VRM	Variable Reluctance Motor
V_{SS}	Ground
V_{SSA}	Analog Ground
WAKE	Wake up Condition
WDE	Watchdog Enable
WP	Write Protect
WSPM	Wait State P Memory
WSX	Wait State Data Memory
WTR	Watchdog Timeout Register
WWW	World Wide Web
XDB2	X Data Bus
XE	X Address Enable
XIE	Index Pulse Interrupt Enable
XIRQ	Index Pulse Interrupt Request
XNE	Use Negative Edge of Index Pulse
XRAM	Data RAM
YE	Y Address Enable
ZCI	Zero Crossing Interrupt
ZCIE	Zero Crossing Interrupt Enable
ZCS	Zero Crossing Status
ZSRC	Zclock Source

Appendix B
Programmer's Sheets

B.1 Introduction

The following pages provide a set of reference tables and programming sheets intended to simplify programming the 56852. The programming sheets provide room to add the value of each bit and the hexadecimal value for each register. These pages may be photocopied.

For complete instruction set details, please refer to Chapter 4 of the 56800E Reference Manual (*DSP56800ERM*).

B.2 Programmer's Sheets

The following pages provide programmer's sheets summarizing functions of the bits in various registers in the 56852. The programmer's sheets provide room to write the value of each bit and the hexadecimal value for each register. These sheets may be photocopied.

The programmer's sheets are arranged corresponding with the sections in this document. **Table B-1** lists the programmer's sheets by module, the registers in each module, and the appendix pages where the programmer's sheets are located.

Note: Reserved bits should always be set to zero unless otherwise stated.

Table B-1. List of Programmer's Sheets

Register Type	Register	Page/Figure
SYSTEM INTEGRATION MODULE (SIM)	**BASE = $1FFF08**	
SIM Control Register	(SCR)	B-6
SIM Control Data Registers 1 & 2	(SCD1-2)	B-7
EXTERNAL MEMORY INTERFACE (EMI)	**BASE = $1FFE40**	
Base Address/Block Size Register	(CSBAR)	B-9
Chip Select Option Register	(CSOR)	B-10
Bus Control Register	(BCR)	B-12
ON CHIP CLOCK SYNTHESIS (OCCS)	**BASE = $1FFFF10**	
CGM Control Register	(CGMCR)	B-13- B-14
CGM Divide-By Register	(CGMDB)	B-15
CGM Time of Day Register	(CGMTOD)	B-16

Table B-1. List of Programmer's Sheets

Register Type	Register	Page/Figure
INTERRUPT CONTROL (ITCN)	**BASE = $1FFF20**	
Interrupt Priority Register 0	(IPR0)	B-20
Interrupt Priority Register 1	(IPR1)	B-21
Interrupt Priority Register 2	(IPR2)	B-22
Interrupt Priority Register 3	(IPR3)	B-23
Interrupt Priority Register 4	(IPR4)	B-24
Interrupt Priority Register 5	(IPR5)	B-25 - B-26
Interrupt Priority Register 6	(IPR6)	B-27 - B-28
Interrupt Priority Register 7	(IPR7)	B-29 - B-30
Vector Base Address Register	(VBA)	B-31
Fast Interrupt Match Register 0	(FIM0)	B-32
Fast Interrupt Match Register 1	(FIM1)	B-33
Fast Interrupt Vector Address Low 0 and High 0	(FIVAL0 and FIVAH0)	B-34
Fast Interrupt Vector Address Low 1 and High 1	(FIVAL1 and FIVAH1)	B-35
Interrupt Request Pending Register 0-3	(IRQP0-3)	B-36
Interrupt Control Register	(ICTL)	B-37 - B-38
SERIAL COMMUNICATION INTERFACE (SCI)	**BASE = $1FFFE0**	
Baud Rate Register	(SCIBR)	B-39
Control Register	(SCICR)	B-40 - B-42
Status Register	(SCISR)	B-43 - B-45
Data Register	(SCIDR)	B-46
SERIAL PERIPHERAL INTERFACE (SPI)	**BASE = $1FFFE8**	
Status and Control Register	(SPSCR)	B-47 - B-49
Data Size and Control Register	(SPDSCR)	B-50
Data Receive Register	(SPDRR)	B-51
Data Transmit Register	(SPDTR)	B-52
IMPROVED SYNCHRONOUS SERIAL INTERFACE (ISSI)	**BASE = $1FFE20**	
Transmit Data Register	(STX)	B-53
Receive Data Register	(SRX)	B-54
Transmit Control Register	(STXCR)	B-55
Receive Control Register	(SRXCR)	B-56
Control/Status Register	(SCSR)	B-57 - B-58
Control/Status Register 2	(SCSR2)	B-59 - B-60
Time Slot Register	(STSR)	B-61
FIFO Control/Status Register	(SFCSR)	B-62 - B-63
Option Register	(SOR)	B-64

Table B-1. List of Programmer's Sheets

Register Type	Register	Page/Figure
QUAD TIMER (TMR)	**BASE = $1FFE80**	
Control Register	(CTL)	B-65 - B-67
Status and Control Register	(SCR)	B-68 - B-69
Compare Register 1	(CMP1)	B-70
Compare Register 2	(CMP2)	B-71
Capture Register	(CAP)	B-72
Load Register	(LOAD)	B-73
Hold Register	(HOLD)	B-74
Counter Register	(CNTR)	B-75
GENERAL PURPOSE IN/OUT (GPIO)	**BASE = $1FFE60**	
Port A Peripheral Enable Register	(MPA_PER)	B-76
Port C Peripheral Enable Register	(MPC_PER)	B-77
Port E Peripheral Enable Register	(MPE_PER)	B-78
Port A Data Direction Register	(MPA_DDR)	B-79
Port C Data Direction Register	(MPC_DDR)	B-80
Port E Data Direction Register	(MPE_DDR)	B-81
Port A Data Register	(MPA_DR)	B-82
Port C Data Register	(MPC_DR)	B-83
Port E Data Register	(MPE_DR)	B-84
Port A Pull-Up Enable Register	(MPA_PUR)	B-85
Port C Pull-Up Enable Register	(MPC_PUR)	B-86
Port E Pull-Up Enable Register	(MPE_PUR)	B-87

Application: _____ Date: _____

Programmer: _____

SIM

System Integration Module Control Register (SCR)

Bits	Name	Description	
14 - 12	BOOT MODE	**Boot Mode**	
		This bit field is set to the value on the input pins, MODC, MODB, and MODA when the last active reset source (accept COP reset) deasserts. Its value determines boot mode executed upon reset.	
		Boot Mode 0	Bootstrap from byte-wide external memory
		Boot Mode 1	Bootstrap from SPI
		Boot Mode 2	Normal expanded mode
		Boot Mode 3	Development expanded mode
		Boot Mode 4	Bootstrap from Host Port-Single Strobe Clocking
		Boot Mode 5	Bookstrap from Host Port-Dual Strobe Clocking
		Boot Mode 6	Bootstrap from SCI
		Boot Mode 7	Reserved
6	EOnCE EBL	**Enhanced OnCE Enable**	
		0	OnCE clock to core is enabled only when the core TAP is enabled
		1	OnCE clock to core is always enabled
5	CLKOUT DBL	**Clock Out Disable**	
		0	CLKOUT output presents CLKMSTR/8 (this is half the peripheral bus clock frequency)
		1	CLKOUT output pin presents static 0
4	PRAM DBL	**Program RAM Disable**	
		0	Internal program RAM enabled
		1	Internal program RAM disabled and accesses redirected to external memory
3	DRAM DBL	**Data RAM Disable**	
		0	Internal data RAM enabled
		1	Internal data RAM disabled and accesses redirected to external memory
2	SW RST	**Software Reset**	
		To reset part, write a 1 to this bit	
1	STOP DBL	**Stop Disable**	
		0	The Stop mode will be entered when the core executes a Stop instruction
		1	The core Stop instruction will not cause entry into the Stop mode
0	WAIT DBL	**Wait Disable**	
		0	The Wait mode will be entered when the core executes a Wait instruction
		1	The core Wait instruction will not cause entry into the Wait mode

SIM Control Register (SCR) $1FFF08 + $0	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	BOOT MODE			CHIP REV				0	EOnCE EBL	CLK OUT DBL	PRAM DBL	DRAM DBL	SW RST	STOP DBL	WAIT DBL
	Write																
	Reset	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

denotes Reserved Bits

SIM

System Integration Module Control Data Registers 1-2 (SCD1-2)

Bits	Name	Description
15-0	SCD1	**Software Control Data One**
		This register is reset only by the POR and is intended for use by software developers to place data to be unaffected by other reset sources.
15-0	SCD2	**Software Control Data Two**
		This register is reset only by the POR and is intended for use by software developers to place data to be unaffected by other reset sources.

SIM Control Data Register 1 (SCD1) $1FFF08 + $1	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	SOFTWARE CONTROL DATA 1															
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SIM Control Data Register 2 (SCD2) $1FFF08 + $2	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	SOFTWARE CONTROL DATA 2															
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Application: _____ Date: _____

_____ Programmer: _____

SIM

System Integration Module Configuration Register (SCR)

Bits	Name	Description	
7	CFG CLKOUT	**Configure Clock-out**	
		0	CLKOUT (SIM)
		1	A[20] (EMI)
6	CFG_A[19]	**Configure A[19] Output**	
		0	A[19] (EMI)
		1	CS3 (EMI)
5	CFG_A[18]	**Configure A[18] Output**	
		0	A[18] (EMI)
		1	TIO1 (TMR)
4	CFG_A[17]	**Configure A[17] Output**	
		0	A[17] (EMI)
		1	TIO0 (TMR)
3	CFG_SCLK	**Configure Serial Clock**	
		0	SCK (SPI)
		1	STCK (SSI)
2	CFG_$\overline{SS}$	**Configure Slave Select Output**	
		0	$\overline{SS}$ (SPI)
		1	STFS (SSI)
1	CFG_MISO	**Configure Master In/Slave Out**	
		0	MISO (SPI)
		1	SRCK (SSI)
0	CFG_MOSI	**Configure Master Out/Slave In**	
		0	MOSI
		1	SRFS (SSI)

SIM Configuration Register (SCFGR) $1FFF08 + $3	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read									CFG CLKOUT	CFG A[19]	CFG A[18]	CFG A[17]	CFG SCLK	CFG $\overline{SS}$	CFG MISO	CFG MOSI
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0[1]	0	0	0	0	0	0

1. Since date code 0302, the ROM Bootcode of the device will change the setting of CFG A[19} to one. It will then be configured as $\overline{CS3}$ and be set to the inactive state, 1. Exercise care when using Boot Mode 2 taking this into consideration.

denotes Reserved Bits

Application: _____ Date: _____

_____ Programmer: _____

EMI

Chip Select Register Base Address and Block Size (CSBAR)

Bits	Name	Description
15	ADDR23	Determines the memory map start address where the chip select is active.
14	ADDR22	
13	ADDR21	
12	ADDR20	
11	ADDR19	
10	ADDR18	
9	ADDR17	
8	ADDR16	
7	ADDR15	
6	ADDR14	
5	ADDR13	
4	ADDR12	
3-0	BLKSZ	Determines which bits in the base address field are compared to corresponding bits on the address bus during an access.

Chip Select Base Address Registers (CSBAR0-CSBAR3) $1FFE40 + $0 - $3	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	ADDR 23	ADDR 22	ADDR 21	ADDR 20	ADDR 19	ADDR 18	ADDR 17	ADDR 16	ADDR 15	ADDR 14	ADDR 13	ADDR 12	BLKSZ			
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

EMI

Chip Select Option Register (CSOR0-3)

Bits	Name	Description
15-11	RWS	**Read Wait States**
		The RWS field specifies the number of additional system clocks, 0-30 (31 is invalid) to delay for read access to the selected memory. The value of RWS should be set as indicated in **the Timing Specifications, Section 5.7.1.**
10-9	BYTE_EN	**Upper/Lower Byte Enable (UBS and LBS)**
		Accesses to external data memory are typically through the use of a word. For data memory access, the 56800 core can also access bytes, yielding the upper and loRWSwer half of a word.

CSOR Encoding of CS UBS Functionality		CSOR Encoding of CS LBS Functionality	
00	Disabled	00	Disabled
01	Lower Byte Enabled	01	Lower Byte Enabled
10	Upper Byte Enabled	10	Upper Byte Enabled
11	Both Bytes Enabled	11	Both Bytes are Enabled

8-7	R/W	**Read/Write**	
		00	The chip select will be disabled
		01	The chip select will be enabled for both read/write
		10	The chip select will allow read only
		11	The chip select will allow read/write
6-5	PS/DS	**Program/Data Space Select**	
		00	The chip select will be disabled
		01	The chip select will allow Data Space only
		10	The chip select will allow Program Space only
		11	The chip select will be enabled
4-0	WWS	**Write Wait State**	
		Specifies minimum number of IPBus_CLK Wait states required by an EMI access.	

Chip Select Option Register (CSOR0-CSOR3) $1FFE40 + $8 - $B	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read / Write	RWS					BYTE_EN		R/W		PS/DS		WWS				
	Reset	1	0	1	1	1	0	0	0	0	0	0	1	0	1	1	1

EMI

Chip Select Timing Control Registers (CSTC0–3)

Bits	Name	Description
15-14	WWSS	**Write Wait States Setup Delay**
		This field affects the write cycle timing diagram. Additional time (clock cycles) is provided between the assertion of CS*n* and address lines and the assertion of WR. The value of WWSS should be set as indicated in Section 5.7.2.
13-12	WWSH	**Write Wait States Hold Delay**
		This field affects the write cycle timing diagram. The WWSH field specifies the number of additional system clocks to hold the address, data, and CS*n* signals after the WR signal is deasserted. The value of WWSH should be set as indicated in Section 5.7.2.
11-10	RWSS	**Read Write States Setup Delay**
		This field affects the read cycle timing diagram. Additional time (clock cycles) is provided between the assertion of CS*n* and address lines and the assertion of RD. The value of RWSS should be set as indicated in Section 5.7.1.
9-8	RWSH	**Read Wait States Hold Delay**
		This field affects the read cycle timing diagram. The RWSH field specifies the number of additional system clocks to hold the address, data, and CS*n* signals after the RD signal is deasserted. The value of RWSH should be set as indicated in Section 5.7.1. **Note:** If both, the RWSS and RWSH fields are set to zero the EMI read timing is set for consecutive mode. In this mode the RD signal will remain active during back-to-back reads from the same CS*n* controlled memory space.
2-0	MDAR	**Minimal Delay After Read**
		This field specifies the number of system clocks to delay between reading from memory in a CS*n* controlled space and reading from another device. Since a write to the device implies activating the Controller on the bus, this is also considered a read from another device. Figure 5-6 illustrates the timing issue requiring the introduction of the MDAR field. In this diagram, CS1 is assumed to operate a slow flash memory in P-space while CS2 is operating a faster RAM in X-space. In some bus contention cases, it is possible to encounter data integrity problems where the contention is occurring at the time the data bus is sampled.

Chip Select Timing Control Registers (CSTC0-CSOR3) $1FFE40 + $10 - $13	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	WWSS		WWSH		RWSS		RWSH		0	0	0	0	0	MDAR		
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

denotes Reserved Bits

EMI

Bus Control Register (BCR)

Bits	Name	Description
15	DRV	**Drive**
		This control bit is used to specify what occurs on the external memory port pins when no external access is performed. For example, it determines whether pins are placed in tri-state or remain driven.
14-12	BMDAR	**Base Minimal Delay After Read**
		This bit field specifies the number of system clocks to delay after reading from memory not in $\overline{CS}$ controlled space. Since a write to the device implies activating the Controller on the bus, this is also considered a read from another device, therefore activating the BMDAR timing control. Please see the description of the MDAR field of the CSTC registers for a discussion of the function of this control.
9-5	BWWS	**Base Write Wait States**
		This bit field specifies the number of additional system clocks 0-30 (31 is invalid) to delay for write access to the selected memory when the memory address does not fall within $\overline{CS}$ controlled range. The value of BWWS should be set as indicated in **Section 5.7.**
4-0	BRWS	**Base Read Wait States**
		This bit field specifies the number of additional system clocks 0-30 (31 is invalid) to delay for read access to the selected memory when the memory address does not fall within $\overline{CS}$ controlled range. The value of BRWS should be set as indicated in **Section 5.7**.

Bus Control Register (BCR) $1FFE40 + $18	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	DRV	BMDAR			0	0	BWWS					BRWS				
	Write																
	Reset	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1	1

denotes Reserved Bits

Application: _____ Date: _____

_____ Programmer: _____

OCCS

CGM Control Register (CGMCR)

Bits	Name	Description
13	LCK1	**Lock 1 Status**
		This bit shows the status of the lock detector state for the LCK1 circuit.
		0 PLL not locked
		1 PLL locked
12	LCK0	**Lock 0 Status**
		This bit shows the status of the lock detector state for the LCK0 circuit.
		0 PLL not locked
		1 PLL locked
11	SEL	**Clock Source Select**
		This bit is used to control the source of the master clock to the SIM.
		0 Oscillator output selected (default)
		1 PLL output selected
6-5	LCK1_IE	**Lock 1 Interrupt Enable**
		This is an optional interrupt bit.
		00 Disable interrupt (default)
		01 Enable interrupt on rising edge of LCK1
		10 Enable interrupt on falling edge of LCK1
		11 Enable interrupt on any edge of LCK1

CGM Control Register (CGMCR) $1FFF10 + $0	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	LCK1	LCK0	SEL	0	0	0	0	LCK1_IE		LCK0_IE		LCKON	TOD_SEL	PDN
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

denotes Reserved Bits

See the following page for continuation of this register

OCCS

CGM Control Register (CGMCR) continued

Bits	Name	Description	
4-3	**LCK0_IE**	**Lock 0 Interrupt Enable**	
		This is an optional interrupt bit.	
		00	Disable interrupt (default)
		01	Enable interrupt on rising edge of LCK0
		10	Enable interrupt on falling edge of LCK0
		11	Enable interrupt on any edge of LCK0
2	**LCKON**	**Lock Detector On**	
		This is an optional interrupt bit.	
		0	Lock detector disabled (default)
		1	Lock detector enabled
1	**TOD_SEL**	**Time of Day Select**	
		This bit is used to select between the two possible TOD_SEL sources.	
		0	TOD_CLK is generated by the oscillator (default)
		1	TOD_CLK is generated by the CGM
0	**PDN**	**The PLL Power-Down**	
		This bit can be turned off by setting the power-down bit to 1.	
		0	PLL turned on
		1	PLL powered down (default)

CGM Control Register (CGMCR) $1FFF10 + $0	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	LCK1	LCK0	SEL	0	0	0	0	LCK1_IE		LCK0_IE		LCKON	TOD_SEL	PDN
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

denotes Reserved Bits

Application: _____ Date: _____

_____ Programmer: _____

OCCS

CGM Divide-By Register (CGMDB)

Bits	Name	Description	
15-13	POST	**PLL Post Scaler**	
		The output of the PLL is postscaled by 1-128 based on this field. To change this field, set the SEL bit to choose the oscillator output, then this field is changed. The SEL bit is then returned to selecting the PLL postscaled output.	
		000	PLL output is divided by 1 (default)
		001	PLL output is divided by 2
		010	PLL output is divided by 4
		011	PLL output is divided by 8
		100	PLL output is divided by 16
		101	PLL output is divided by 32
		110	PLL output is divided by 64
		111	PLL output is divided by 128
6 - 0	PLLDB	**PLL Divide-By**	
		The PLL output frequency is controlled by the PLL divide-by value. Each time a new value is written into the PLLDB field, the Lock Detector circuit is reset. Before changing the divide-by, set the SEL bit to choose the oscillator output.	

CGM Divide-By Register (CGMDB) $1FFF10 + $1	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	POST			0	0	0	0	0	0	PLLDB						
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1

denotes Reserved Bits

OCCS

CGM Time-of-Day Register (CGMTOD)

Bits	Name	Description
11 - 0	TOD	**Time-of-Day**
		The output of the oscillator is divided by (TOD + 1) and then divided by 2 to generate the TOD clock used by the COP module when TOD_SEL is high. The value of TOD should be chosen to result in a TOD clock frequency in the range of 15.12KHz to 31.25KHz. This register is only reset during Power-On Reset (POR).

CGM Time-of-Day Register (CGMTOD) $1FFF10 + $2	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	TOD											
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

Application: _____ Date: _____

Programmer: _____

COP

COP Control Register (COPCTL)

Bits	Name	Description
4	BYPS	**BYPASS (For factory use only)**
		When this bit is set, it allows factory testing of the COP is accelerated by routing the IPBus clock to the counter instead of the OSCCLK. This bit should not be set during normal chip operation.
3	CSEN	**COP Stop Enable**
		This bit controls the operation of the COPcounter Stop mode. It can be changed only when the CWP bit is set to zero.
2	CWEN	**COP Wait Enable**
		This bit controls the operation of the COP counter in the Wait mode. It can be changed only when the CWP bit is set to zero.
1	CEN	**COP Enable**
		This bit controls the operation of the COP counter. This bit can only be changed when CWP is set to zero. This bit *always* reads as zero when the chip is in the Debug mode.
0	CWP	**COP Write Protect**
		This bit controls the write protection feature of the COP Control (COPCTL) and the COP Timeout (COPTO) registers. Once set, this bit can only be cleared by resetting the module.

COP Control Register (COPCTL) $1FFFD0 + $0	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	0	0	0	BYPS	CSEN	CWEN	CEN	CWP
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

COP

COP Time-out Register (COPTO)

Bits	Name	Description
15 - 0	TIMEOUT	**COP Time-Out Period**
		This register determines the timeout period of the COP counter. TIMEOUT should be written before the COP is enabled. Once the COP is enabled, the recommended procedure for changing TIMEOUT is to disable the COP, write to COPTO, then re-enable the COP, ensuring the new TIMEOUT is loaded into the counter. Alternatively, the CPU can write to COPTO, then write the proper patterns to COPCTR, causing the counter to reload with the new TIMEOUT value. The COP counter is not reset by a write to COPTO. Changing TIMEOUT while the COP is enabled will result in a timeout period differing from the expected value. These bits can only be changed when the CWP bit is set to zero.

COP Timeout Register (COPTO) $1FFFD0 + $1	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	TIMEOUT															
	Write																
	Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Application: _____ Date: _____

Programmer: _____

COP

COP Counter Register (COPCTR)

Bits	Name	Description
15 - 0	COPCTR	**COP Counter(Count)**
		This is the current value of the COP counter as it counts down from the timeout value to zero. A reset is issued when this count reaches zero.
15 - 0	COPCTR	**COP Counter (Service)**
		When enabled, the COP requires a service sequence be performed periodically in order to clear the COP counter and prevent a reset from being issued. This routine consists of writing $5555 to the COPCTR followed by writing $AAAA before the timeout period expires. The writes to COPCTR must be performed in the correct order, but any number of other instructions, and writes to other registers, may be executed between the two writes.

COP Counter Register (COPCTR) $1FFFD0 + $2	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	COUNT															
	Write	SERVICE															
	Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Application: _____ Date: _____

_____ Programmer: _____

ITCN

Interrupt Priority Register 0 (IPR0)

Bits	Name	Description	
13-12	BKPT_U0 IPL	**Breakpoint Unit 0 EOnCE Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this EOnCE IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 1
		10	IRQ is priority level 2
		11	IRQ is priority level 3
11-1 0	STPCENT IPL	**EOnCE Step Counter Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this EOnCE IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 1
		10	IRQ is priority level 2
		11	IRQ is priority level 3

Interrupt Priority Register 0 (IPR0) $1FFF20 + $0	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	BKPT_U0 IPL		STPCNT IPL		0	0	0	0	0	0	0	0	0	0
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ITCN

Interrupt Priority Register 1 (IPR1)

Bits	Name	Description	
5 - 4	RX_REG IPL	**Receive Data Empty Register Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this OnCE IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 1
		10	IRQ is priority level 2
		11	IRQ is priority level 3
3 - 2	TX_REG IPL	**Transmit Data Full Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this OnCE IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 1
		10	IRQ is priority level 2
		11	IRQ is priority level 3
1 - 0	TRBUF IPL	**Trace Buffer Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this OnCE IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 1
		10	IRQ is priority level 2
		11	IRQ is priority level 3

Interrupt Priority Register 1 (IPR1) $1FFF20 + $1	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	0	0	RX_REG IPL		TX_REG IPL		TRBUF IPL	
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ITCN

Interrupt Priority Register 2 (IPR2)

Bits	Name	Description
7 - 6	LOCK IPL	**Loss of Lock Interrupt Priority Level**
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.
		00 IRQ disabled by default
		01 IRQ is priority level 0
		10 IRQ is priority level 1
		11 IRQ is priority level 2
3 - 2	IRQB IPL	**External IRQB Interrupt Priority Level**
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.
		00 IRQ disabled by default
		01 IRQ is priority level 0
		10 IRQ is priority level 1
		11 IRQ is priority level 2
1 - 0	IRQA IPL	**External IRQA Interrupt Priority Level**
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.
		00 IRQ disabled by default
		01 IRQ is priority level 0
		10 IRQ is priority level 1
		11 IRQ is priority level 2

Interrupt Priority Register 2 (IPR2) $1FFF20 + $2	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	LOCK IPL		0	0	IRQB IPL		IRQA IPL	
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ITCN

Interrupt Priority Register 3 (IPR3)

Bits	Name	Description	
15-14	ISSI_TD IPL	**ISSI Transmit Data Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2
13-12	ISSI_TDES IPL	**ISSI Transmit Data with Exception Status Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2
9 - 8	ISSI_RD IPL	**ISSI Receive Data Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2
7 - 6	ISSI_RDES IPL	**ISSI Receive Data with Exception Status Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2

Interrupt Priority Register 3 (IPR3) $1FFF20 + $3	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	ISSI_TD IPL		ISSI_TDES IPL		0	0	ISSI_RD IPL		ISSI_RDES IPL		0	0	0	0	0	0
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ITCN

Interrupt Priority Register 4 (IPR4)

Bits	Name	Description	
15-14	SPI_RCV IPL	**SPI Receiver Full Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2

Interrupt Priority Register 4 (IPR4) $1FFF20 + $4	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	SPI_RCV IPL		0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ITCN

Interrupt Priority Register 5 (IPR5)

Bits	Name	Description	
11-10	SCI_RCV IPL	**SCI Receive Full Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2
9 - 8	SCI_RERR IPL	**SCI Receive Error Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2
7 -6	SCI_RIDL IPL	**SCI Receive Idle Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2

Interrupt Priority Register 5 (IPR5) $1FFF20 + $5	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	SCI_RCV IPL		SCI_RERR IPL		SCI_RIDL IPL		SCI_TDL IPL		SCI_XMIT IPL		SPI_XMIT IPL	
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

See the following page for continuation of this register

ITCN

Interrupt Priority Register 5 (IPR5) continued

Bits	Name	Description
5 - 4	SCI_TIDL IPL	**SCI Transmitter Idle Interrupt Priority Level**
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.
		00 IRQ disabled by default
		01 IRQ is priority level 0
		10 IRQ is priority level 1
		11 IRQ is priority level 2
3 - 2	SCI_XMIT IPL	**SCI Transmitter Empty Interrupt Priority Level**
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.
		00 IRQ disabled by default
		01 IRQ is priority level 0
		10 IRQ is priority level 1
		11 IRQ is priority level 2
1 - 0	SPI_XMIT IPL	**SPI Transmitter Empty Interrupt Priority Level**
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.
		00 IRQ disabled by default
		01 IRQ is priority level 0
		10 IRQ is priority level 1
		11 IRQ is priority level 2

Interrupt Priority Register 5 (IPR5) $1FFF20 + $5	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	SCI_RCV IPL		SCI_RERR IPL		SCI_RIDL IPL		SCI_TDL IPL		SCI_XMIT IPL		SPI_XMIT IPL	
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ITCN

Interrupt Priority Register 6 (IPR6)

Bits	Name	Description	
15-14	TOVF1 IPL	**Timer Overflow 1 Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2
13-12	TCMP1 IPL	**Timer Compare 1 Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2
11-10	TINP0 IPL	**Timer Input Edge 0 Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2

Interrupt Priority Register 6 (IPR6) $1FFF20 + $6	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	TOVF1 IPL		TCMP1 IPL		TINP0 IPL		TOVF0 IPL		TCMP0 IPL		0	0	0	0	0	0
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

See the following page for continuation of this register

ITCN

Interrupt Priority Register 6 (IPR6) continued

Bits	Name	Description	
9 - 8	TOVF0 IPL	**Timer Overflow 0 Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2
7 -6	TCMP0 IPL	**Timer Compare 0 Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2

Interrupt Priority Register 6 (IPR6) $1FFF20 + $6	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	TOVF1 IPL		TCMP1 IPL		TINP0 IPL		TOVF0 IPL		TCMP0 IPL		0	0	0	0	0	0
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ITCN

Interrupt Priority Register 7 (IPR7)

Bits	Name	Description
13-12	TINP3 IPL	**Timer Input Edge 3 Interrupt Priority Level**
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.
		00 IRQ disabled by default
		01 IRQ is priority level 0
		10 IRQ is priority level 1
		11 IRQ is priority level 2
11-10	TOVF3 IPL	**Timer Overflow 3 Interrupt Priority Level**
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.
		00 IRQ disabled by default
		01 IRQ is priority level 0
		10 IRQ is priority level 1
		11 IRQ is priority level 2
9 - 8	TCMP3 IPL	**Timer Compare 3 Interrupt Priority Level**
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.
		00 IRQ disabled by default
		01 IRQ is priority level 0
		10 IRQ is priority level 1
		11 IRQ is priority level 2
7 - 6	TINP2 IPL	**Timer Input Edge 2 Interrupt Priority Level**
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.
		00 IRQ disabled by default
		01 IRQ is priority level 0
		10 IRQ is priority level 1
		11 IRQ is priority level 2

Interrupt Priority Register 7 (IPR7) $1FFF20 + $7	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	TINP3 IPL		TOVF3 IPL		TCMP3 IPL		TINP2 IPL		TOVF2 IPL		TCMP2 IPL		TINP1 IPL	
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

See the following page for continuation of this register

ITCN

Interrupt Priority Register 7 (IPR7) continued

Bits	Name	Description	
5 - 4	TOVF2 IPL	**Timer Overflow 2 Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2
3 - 2	TCMP2 IPL	**Timer Compare 2 Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2
1 - 0	TINP1 IPL	**Timer Input Edge 1 Interrupt Priority Level**	
		This bit field is used to set the interrupt priority levels for this peripheral IRQ.	
		00	IRQ disabled by default
		01	IRQ is priority level 0
		10	IRQ is priority level 1
		11	IRQ is priority level 2

Interrupt Priority Register 7 (IPR7) $1FFF20 + $7	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	TINP3 IPL		TOVF3 IPL		TCMP3 IPL		TINP2 IPL		TOVF2 IPL		TCMP2 IPL		TINP1 IPL	
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ITCN

Vector Base Address Register (VBA)

Bits	Name	Description
12 - 0	VBA	**Vector Base Address**
		The value in this register is used as the upper 13 bits of the interrupt vector VAB[20:0]. The lower eight bits are determined based on the highest priority interrupt, which are appended onto VBA before presenting the full VAB to the core.

Vector Base Address Register (VBA) $1FFF20 + $8	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	VECTOR BASE ADDRESS												
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ITCN

Fast Interrupt Match Register 0 (FIM0)

Bits	Name	Description
5 - 0	FIM0	**Fast Interrupt Match 0**
		This value is used to declare which two IRQs will be Fast Interrupts. Fast Interrupt vector directly to a service routine based on values in the Fast Interrupt Vector Address registers without having to go to a jump table first. IRQs used as fast interrupts must be set to priority level two. Unexpected results will occur if a fast interrupt vector is set to any other priority. Fast interrupts automatically become the highest priority level two interrupts regardless of their actual location in the interrupt table prior to being declared fast interrupts. Fast Interrupt 0 has priority over Fast Interrupt 1.

Fast Interrupt Match Register 0 (FIM0) $1FFF20 + $9	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	0	0	FAST INTERRUPT 0					
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ITCN

Fast Interrupt Match Register 1 (FIM1)

Bits	Name	Description
5 - 0	FIM1	**Fast Interrupt Match 1**
		This value is used to declare which two IPQs will be Fast Interrupts. Fast Interrupt vector directly to a service routine based on values in the Fast Interrupt Vector Address registers without having to go to a jump table first. IRQs used as fast interrupts must be set to priority level two. Unexpected results will occur if a fast interrupt vector is set to any other priority. Fast interrupts automatically become the highest priority level two interrupts regardless of their actual location in the interrupt table prior to being declared fast interrupts. Fast Interrupt 0 has priority over Fast Interrupt 1.

Fast Interrupt Match Register 1 (FIM1) $1FFF20 + $C	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	0	0	FAST INTERRUPT 1					
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ITCN

Fast Interrupt Vector Address Low 0 and High 0 (FIVAL0, FIVAH0)

Bits	Name	Description
15 - 0	**FIVAL0**	**Fast Interrupt Vector Address Low 0**
		This register is combined with the FIVAH0 register to forma 21-bit vector address for the fast interrupt defined in the FIVAL0 and FIVAH0 registers. Lower 16 bits of vector address for fast interrupt 0.

Fast Interrupt Vector Address Low 0 (FIVAL0) $1FFF20 + $A	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	FAST INTERRUPT 0 VECTOR ADDRESS LOW															
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

BITS	NAME	Description
4 - 0	**FIVAH0**	**Fast Interrupt Vector Address High 0**
		This register is combined with the FIVAL0 register to form a 21-bit vector address for the fast interrupt defined in the FIVAL0 and FIVAH0 registers. Upper 5 bits of vector address for fast interrupt 0.

Fast Interrupt Vector Address High 0 (FIVAH0) $1FFF20 + $B	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	0	0	0	FAST INTERRUPT 0 VECTOR ADDRESS HIGH				
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ITCN

Fast Interrupt Vector Address Low 1 and High 1 (FIVAL1, FIVAH1)

Bits	Name	Description
15 - 0	FIVAL1	**Fast Interrupt Vector Address Low 1**
		This register is combined with the FIVAH1 register to form A21-bit vector address for the fast interrupt defined in the FIVAL1 and FIVAH1 registers. Lower 16 bits of vector address for fast interrupt 1.

Fast Interrupt Vector Address Low 1 (FIVAL1) $1FFF20 + $D	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	FAST INTERRUPT 1 VECTOR ADDRESS LOW															
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Bits	Name	Description
4 - 0	FIVAH1	**Fast Interrupt Vector Address High 1**
		This register is combined with the FIVAL1 register to form A 21-bit vector address for the fast interrupt defined in the FIVAL1 and FIVAH1 registers. Upper 5 bits of vector address for fast interrupt 1.

Fast Interrupt Vector Address High 1 (FIVAL1) $1FFF20 + $E	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	0	0	0	FAST INTERRUPT 1 VECTOR ADDRESS HIGH				
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ITCN

IRQ Pending Registers 0 - 3 (IRQP0 - IRQP3)

Bits	Name	Description	
64 - 1	IRQP0 - 3	**IRQ Pending Registers**	
		These registers combine to show the status of interrupt requests 2 through 64.	
		0	IRQ pending for this vector number
		1	No IRQ pending for this vector number

IRQ Pending Register 0 (IRQP0) $1FFF20 + $F	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	PENDING [16:1]															1
	Write																
	Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

IRQ Pending Register 1 (IRQP1) $1FFF20 + $10	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	PENDING [32:17]															
	Write																
	Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

IRQ Pending Register 2 (IRQP2) $1FFF20 + $11	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	PENDING [48:33]															
	Write																
	Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

IRQ Pending Register 3 (IRQP3) $1FFF20 + $12	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	PENDING [64:49]															
	Write																
	Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

denotes Reserved Bits

ITCN

Interrupt Control Register (ICTL)

Bits	Name	Description	
15	INT	**Interrupt**	
		0	No interrupt is being presented to the core
		1	An interrupt is being presented to the core
14-13	IPLC	**Interrupt Priority Level Core**	
		This bit field reflects the state of the new interrupt priority level bits being presented to the core at the time the last IRQ was taken.	
		00	Required nested exception priority levels are 0, 1, 2, or 3
		01	Required nested exception priority levels are 1, 2, or 3
		10	Required nested exception priority levels are 2 or 3
		11	Required nested exception priority level is 3
12 - 6	VN	**Vector Number**	
		This field shows bits [7:1] of the Vector Number of the last IRQ. The field is only updated when the core jumps to a new interrupt service routine.	
5	INT_DIS	**Interrupt Disable**	
		Disables all interrupts	
		0	Normal operation (default)
		1	All interrupts disabled

IRQ Control Register (ICTL) $1FFF20 + $17	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	INT	IPLC		VN							INT_DIS	0	IRQA STATE	IRQB STATE	IRQB EDG	IRQA EDG
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0

denotes Reserved Bits

See the following page for continuation of this register

ITCN

Interrupt Control Register (ICTL) continued

Bits	Name	Description	
3	IRQB STATE	**State of $\overline{\text{IRQB}}$**	
		This bit reflects the state of the external $\overline{\text{IRQB}}$	
2	IRQA STATE	**State of $\overline{\text{IRQA}}$**	
		This bit reflects the state of the external $\overline{\text{IRQA}}$	
1	IRQB EDG	**$\overline{\text{IRQB}}$ Edge**	
		This bit controls whether the external $\overline{\text{IRQB}}$ interrupt is edge or level sensitive. Automatically level sensitive during Stop and Wait modes.	
		0	$\overline{\text{IRQB}}$ interrupt is level sensitive (default)
		1	$\overline{\text{IRQB}}$ interrupt is falling edge sensitive
0	IRQA EDG	**$\overline{\text{IRQA}}$ Edge**	
		This bit controls whether the external $\overline{\text{IRQA}}$ interrupt is edge or level sensitive. Automatically level sensitive during Stop and Wait modes.	
		0	$\overline{\text{IRQA}}$ interrupt is low level sensitive (default)
		1	$\overline{\text{IRQA}}$ interrupt is falling edge sensitive

IRQ Control Register (ICTL) $1FFF20 + $17

Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	INT	IPLC		VN							INT_DIS	0	IRQA STATE	IRQB STATE	IRQB EDG	IRQA EDG
Write																
Reset	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0

denotes Reserved Bits

SCI

SCI Baud Rate Register (SCIBR)

Bits	Name	Description
12 - 0	SBR	**SCI Baud Register**
		This register may be read at any time. Bits 12 through 0 can be written at any time. (SBR = contents of the baud rate registers, a value from 1 to 8191.)

SCI Baud Rate Register (SCIBR) $1FFFE0 + $0	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	SBR												
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

SCI

SCI Control Register (SCICR)

Bits	Name	Description	
15	LOOP	**Loop Select**	
		This bit enables loop operation. Loop operation disconnects the RXD pin from the SCI and the transmitter output goes into the receiver input. Both transmitter and receiver must be enabled to use the internal loop function as opposed to single wire operation, requiring only one or the other to be enabled.	
		0	Normal operation enabled
		1	Loop operation enabled
14	SWAI	**Stop in Wait Mode**	
		This bit disables the SCI in the Wait mode.	
		0	SCI enabled in Wait mode
		1	SCI disabled in Wait mode
13	RSRC	**Receiver Source**	
		When LOOP = 1, the RSRC bit determines the internal feedback path for the receiver.	
		0	Receiver input internally connected to transmitter output
		1	Receiver input connected to TXD pin
12	M	**Data Format Mode**	
		The Mode bit determines whether data characters are eight or nine bits long.	
		0	One start bit, eight data bits, one stop bit
		1	One start bit, nine data bits, one stop bit
11	WAKE	**Wake up Condition**	
		This bit determines which condition wakes up the SCI.	
		0	Idle line wake up
		1	Address mark wake up
10	POL	**Polarity**	
		This bit determines whether to invert the data as it goes from the transmitter to the TXD pin and from the RXD pin to the receiver. All bits (Start, Data, and Stop) will be inverted as they leave the transmit shift register and before they enter the receive shift register.	
		0	Doesn't invert transmit and receive data bits (Normal mode)
		1	Invert transmit and receive data bits (Inverted mode)

SCI Control Register (SCICR) $1FFFE0 + $1	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	LOOP	SWAI	RSRC	M	WAKE	POL	PE	PT	TEIE	TIIE	RFIE	REIE	TE	RE	RWU	SBK
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

See the following page for continuation of this register

SCI

SCI Control Register (SCICR) continued

Bits	Name	Description	
9	PE	**Parity Enable**	
		This bit enables the parity function. When enabled, the function replaces the most significant bit of the data character with a parity bit.	
		0	Parity function disabled
		1	Parity function enabled
8	PT	**Parity Type**	
		This bit determines if the SCI generates and checks for even or odd parity of the data bits.	
		0	Even Parity
		1	Odd parity
7	TEIE	**Transmitter Empty Interrupt Enable**	
		This bit enables Transmit Data Register Empty (TDRE) flag to generate interrupt requests.	
		0	TDRE interrupt requests disabled
		1	TDRE interrupt requests enabled
6	TIIE	**Transmitter Idle Interrupt Enable**	
		This bit enables the Transmitter Idle (TIDLE) flag to generate interrupt requests.	
		0	TIDLE interrupt requests disabled
		1	TIDLE interrupt requests enabled
5	RFIE	**Receiver Full Interrupt Enable**	
		This bit enables the Receive Data Register Full (RDRF) flag, or the Overrun (OR) flag to generate interrupt requests.	
		0	RDRF and OR interrupt requests disabled
		1	RDRF and OR interrupt requests enabled

SCI Control Register (SCICR) $1FFFE0 + $1	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	LOOP	SWAI	RSRC	M	WAKE	POL	PE	PT	TEIE	TIIE	RFIE	REIE	TE	RE	RWU	SBK
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

See the following page for continuation of this register

SCI

SCI Control Register (SCICR) continued

Bits	Name	Description	
4	REIE	**Receiver Error Interrupt Enable**	
		This bit enables Receive Error (RE) flags (NF, PF, FE, an OR) to create interrupt requests.	
		0	Error interrupt requests disabled
		1	Error interrupt requests enabled
3	TE	**Transmitter Enable**	
		This bit enables the SCI transmitter, configuring the TXD pin as the SCI transmitter output.	
		0	Transmitter disabled
		1	Transmitter enabled
2	RE	**Receiver Enable**	
		This bit enables the SCI receiver.	
		0	Receiver disabled
		1	Receiver enabled
1	RWU	**Receiver Wake up**	
		This bit enables the wake up function and inhibits further receiver interrupt requests.	
		0	Standby state
		1	Normal operation
0	SBK	**Send Break**	
		Toggling SBK sends one break character (10 or 11 Logic 0s). As long as SBK is set, the transmitter sends Logic 0s.	
		0	No break characters
		1	Transmit break characters

SCI Control Register (SCICR) $1FFFE0 + $1	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	LOOP	SWAI	RSRC	M	WAKE	POL	PE	PT	TEIE	TIIE	RFIE	REIE	TE	RE	RWU	SBK
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SCI

SCI Status Register (SCISR)

Bits	Name	Description	
15	TDRE	**Transmit Data Register Empty**	
		This bit is set when the transmit shift register receives a character from the SCI Data Register (SCIDR). Clear TDRE by reading SCISR with TDRE set and then writing to SCI data register in normal mode or by writing the SCIDR with TDE set.	
		0	No character transferred to transmit shift register
		1	Character transferred to transmit shift register; transmit data register empty
14	TIDLE	**Transmitter Ilde**	
		This bit is set when the TDRE flag is set and not data, preamble, or break character is being transmitted. When TIDLE is set, the TXD pin becomes idle (Logic 1). Clear TIDLE by reading the SCI Status Register (SCISR) with TIDLE set and then writing to the SCI Data Register (SCIDR). TIDLE is not generated when a data character, a preamble, or a break is queued and ready to be sent.	
		0	Transmission in progress
		1	No transmission in progress
13	RDRF	**Receive Data Register Full**	
		This bit is set when the data in the receive shift register transfers to the SCI Data Register (SCIDR) Clear RDRF by reading the SCI Status Register (SCISR) with RDRF set and then reading the SCI data register in normal mode or by reading the SCIDR with RDE set.	
		0	Data not available in SCI data register
		1	Received data available in SCI data register

SCI Status Register (SCISR) $1FFFE0 + $3	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	TDRE	TIDLE	RDRF	RIDLE	OR	NF	FE	PF	0	0	0	0	0	0	0	RAF
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

See the following page for continuation of this register

denotes Reserved Bits

SCI

SCI Status Register (SCISR) continued

Bits	Name	Description	
12	RIDLE	**Receiver Idle Line**	
		This bit is set when 10 consecutive Logic 1s (if M = 0) or 11 consecutive Logic 1s (if M = 1) appear on the receiver input. Once the RIDLE flag is cleared (the receiver detects a Logic 0), a valid frame must again set the RDRF flag before an idle condition can set the RIDLE flag.	
		0	Receiver input is either active now or has never become active since the RIDLE flag was last cleared
		1	Receiver input has become idle (after receiving a valid frame)
11	OR	**Overrun**	
		This bit is set when software fails to read the SCI Data Register (SCIDR) before the receive shift register receives the next frame. The data in the shift register is lost, but the data already in the SCI data register is not affected. Clear OR by reading the SCI Status Register (SCISR) with OR set and then writing the SCI status register with any value.	
		0	No overrun
		1	Overrun

SCI Status Register (SCISR) $1FFFE0 + $3	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	TDRE	TIDLE	RDRF	RIDLE	OR	NF	FE	PF	0	0	0	0	0	0	0	RAF
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

See the following page for continuation of this register

denotes Reserved Bits

SCI

SCI Status Register (SCISR) continued

Bits	Name	Description
10	NF	**Noise Flag**
		This bit is set when the SCI detects noise on the receiver input. The NF bit is set during the same cycle as the RDRF flag but does not get set in the case of an overrun. Clear NF by reading the SCI Status Register (SCISR) and then writing the SCI status register with any value.
		0 No noise
		1 Noise
9	FE	**Framing Error**
		This bit is set when a Logic 0 is accepted as the stop bit. The FE bit is set during the same cycle as the RDRF flag but does not get set in the case of an overrun. FE inhibits further data reception until it is cleared. Clear FE by reading the SCI Status Register (SCISR) with FE set and then writing the SCI status register with any value.
		0 No framing error
		1 Framing error
8	PF	**Parity Error Flag**
		This bit is set when the parity enable PE bit is set and the parity of the received data does not match its parity bit. Clear PF by reading the SCI Status Register (SCISR) and then writing the SCI status register with any value.
		0 No parity error
		1 Parity error
0	RAF	**Receiver Active Flag**
		This bit is set when the receiver detects a Logic 0 during the RT1 time period of the start bit search. RAF is cleared when the receiver detects false start bits (usually from noise or baud rate mismatch) or when the receiver detects a preamble.
		0 No reception in progress
		1 Reception in progress

SCI Status Register (SCISR) $1FFFE0 + $3	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	TDRE	TIDLE	RDRF	RIDLE	OR	NF	FE	PF	0	0	0	0	0	0	0	RAF
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

SCI

SCI Data Register (SCIDR)

Bits	Name	Description
8 - 0	**Receive Data**	Receive Data
8 - 0	**Transmit Data**	Data to be Transmitted

SCI Data Register (SCIDR) $1FFFE0 + $4	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	RECEIVE DATA								
	Write								TRANSMIT DATA								
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

Application: _____ Date: _____

Programmer: _____

SPI

SPI Status and Control Register (SPSCR)

Bits	Name	Description
15-13	SPR	**SPI Baud Rate**
		These are read/write bits while in Master mode, selects one of four baud rates.
12	DSO	**Data Shift Order**
		This read/write bit determines whether the MSB or LSB bit is transmitted or received first.
		0 MSB transmitted first (MSB->LSB)
		1 LSB transmitted first (LSB->MSB)
11	ERRIE	**Error Interrupt Enable**
		This read/write bit enables the MODF and OVRF bits to generate interrupt requests. Reset clears the ERRIE bit. ERRIE bit enables both the MODF and OVRF bits to generate a receiver/error interrupt request.
		0 MODF and OVRF cannot generate interrupt requests
		1 MODF and OVRF can generate interrupt requests
10	MODFEN	**Mode Fault Enable**
		This read/write bit when set to one allows the MODF flag to be set. If the MODF flag is set, clearing the MODFEN does not clear the MODF flag.
9	SPRIE	**SPI Receiver Interrupt Enable**
		This read/write bit enables interrupt requests generated by the SPRF bit. The SPRF bit is set when a full data length transfers from the Shift Register to the Receive Data Register.
		0 SPRF interrupt requests disabled
		1 SPRF interrupt requests enabled
8	SPMSTR	**SPI Master**
		This read/write bit selects Master mode operation or slave mode operation.
		0 Slave mode
		1 Master mode

SPI Status and Control Register (SPSCR) $1FFFE8 + $0	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	SPR			DSO	ERRIE	MODFEN	SPRIE	SPMSTR	CPOL	CPHA	SPE	SPTIE	SPRF	OVRF	MODF	SPTE
	Write																
	Reset	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0

See the following page for continuation of this register

denotes Reserved Bits

SPI

SPI Status and Control Register (SPSCR) continued

Bits	Name	Description
7	CPOL	**Clock Parity**
		This read/write bit determines the logic state of the SCLK pin between transmissions. To transmit data between SPI modules, the SPPI modules musts have identical CPOL values.
		0 Falling edge of SCLK starts transmission
		1 Rising edge of the SCLK starts transmission
6	CPHA	**Clock Phase**
		This read/write bit controls the timing relationship between the serial clock and SPI data. To transmit data between SPI modules, there must be identical CPHA values. When CPHA = 0, the $\overline{SS}$ pin of the Slave SPI module musts be set to Logic 1 between full length data transmissions.
5	SPE	**SPI Enable**
		This read/write bit enables the SPI module. Clearing SPE causes a partial reset of the SPI. When setting/clearing this bit, no other bits in the SPSCR should be changed. Failure to following this statement may result in spurious clocks.
		0 SPI module disabled
		1 SPI module enabled
4	SPTIE	**SPI Transmit Interrupt Enable**
		This read/write bit enables interrupt requests generated by the SPTE bit. SPTE is set when a full data length transfers from the Transmit Data Register to the Shift Register.
		0 SPTE interrupt requests disabled
		1 SPTE interrupt request enabled
3	SPRF	**SPI Receiver Full**
		This *read-only* flag enables interrupt requests generated by the SPTE bit.
		0 Receive Data Register not full
		1 Receive Data Register full

SPI Status and Control Register (SPSCR) $1FFFE8 + $0	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	SPR			DSO	ERRIE	MODFEN	SPRIE	SPMSTR	CPOL	CPHA	SPE	SPTIE	SPRF	OVRF	MODF	SPTE
	Write																
	Reset	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0

See the following page for continuation of this register

denotes Reserved Bits

SPI

SPI Status and Control Register (SPSCR) continued

Bits	Name	Description
2	OVRF	**Overflow**
		This *read-only* flag is set if software does not read the data in the Receive Data Register before the next full data enters the Shift Register.
		0 — No overflow
		1 — Overflow
1	MODF	**Mode Fault**
		This *read-only* flag is set in a slave SPI if the $\overline{SS}$ pin goes high during a transmission with the MODFEN bit set.
		0 — $\overline{SS}$ pin at appropriate logic level
		1 — $\overline{SS}$ pin at inappropriate logic level
0	SPTE	**SPI Transmitter Empty**
		This *read-only* flag is set each time the Transmit Data Register transfers a full data length into the Shift Register.
		0 — Transmit Data Register not empty
		1 — Transmit Data Register empty

SPI Status and Control Register (SPSCR) $1FFFE8 + $0	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	SPR			DSO	ERRIE	MODFEN	SPRIE	SPMSTR	CPOL	CPHA	SPE	SPTIE	SPRF	OVRF	MODF	SPTE
	Write																
	Reset	0	1	1	0	0	0	0	1	0	1	0	0	0	0	0	0

denotes Reserved Bits

SPI

SPI Data Size and Control Register (SPDSCR)

Bits	Name	Description			
15	WOM	**Wired OR Mode**			
		0	Wired OR mode disabled		
		1	Wired OR mode enabled		
3 - 0	TDS	**Transmission Data Size**			
		Detailed transmission data provided in the following table:			
		DS3 - DS0	**Size of Transmission**	**DS3 - DS0**	**Size of Transmission**
		$0	Not Allowed	$8	9 Bits
		$1	2 Bits	$9	10 Bits
		$2	3 Bits	$A	11 Bits
		$3	4 Bits	$B	12 Bits
		$4	5 Bits	$C	13 Bits
		$5	6 Bits	$D	14 Bits
		$6	7 Bits	$E	15 Bits
		$7	8 Bits	$F	16 Bits

SPI Data Size and Control Register (SPDSCR) $1FFFE8 + $1	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	WOM	0	0	0	0	0	0	0	0	0	0	0	TDS			
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1

denotes Reserved Bits

SPI

SPI Data Receive Register (SPDRR)

Bits	Name	Description
15 - 0	R	**Receive**
		This is a *read-only* data register. Reading data from the register will show the last full data received after a complete transmission. The SPRF bit will set when new data transfers to this register.

SPI Data Receive Register (SPDRR) $1FFFE8 + $2	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	R15	R14	R13	R12	R11	R10	R9	R8	R7	R6	R5	R4	R3	R2	R15	R0
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

SPI

SPI Data Transmit Register (SPDTR)

Bits	Name	Description
15 - 0	T	**Transmit**
		This is a *write-only* data register. Writing data to the register modifies data to the transmit data buffer. When the SPTE bit is set, new data should be written to this register. If new data is not written while in the Master mode, a new transaction will not be initiated until this register is written. When in the Slave mode, the old data will be re-transmitted. All data should be written with the LSB at bit 0.

SPI Data Transmit Register (SPDTR) $1FFFE8 + $3	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Write	T15	T14	T13	T12	T11	T10	T9	T8	T7	T6	T5	T4	T3	T2	T1	T0
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ISSI

ISSI Transmit Data Register (STX)

Bits	Name	Description
15 -0	DATA	**Read Data**
		STX is a 16-bit read/write data register.

ISSI Transmit Data Register (STX) $1FFE20 + $0	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	DATA															
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ISSI

ISSI Receive Data Register (SRX)

Bits	Name	Description
15 -8	HIGH BYTE	SRX is a *read-only* register. The register always accepts data from the Receiver Shift Register as it becomes full.
7 -0	LOW BYTE	

ISSI Receive Data Register (SRX) $1FFE20 + $1	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	HIGH BYTE								LOW BYTE							
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ISSI

ISSI Transmit Control Register (STXCR)

Bits	Name		Description
15	PSR	**Prescaler Range**	
		0	Prescaler is bypassed
		1	Divide-by-eight prescaler is operational
14 - 13	WL	**Word Length Control**	
		Used to select the length of the data words. See the following table	
		00	Number of bits/words 8
		01	Number of bits/words 10
		10	Number of bits/words 12
		11	Number of bits/words 16
12 - 8	DC	**Frame Rate Divider Control**	
		Control the divide ratio for programmable frame rate dividers. The divide ratio ranges from 1 to 32 (DC[4:0]=00000 to 11111) in Normal mode and from 2 to 32 (DC[4:0]=00001 to 11111) in Network mode.	
7 - 0	PM	**Prescaler Modulus Select**	
		Specify the divide ratio of the prescale divider in the SSI clock generator. A divide ratio from 1 to 256 (PM[7:0]=$00 to $FF) can be selected.	

ISSI Transmit Control Register (STXCR) $1FFE20 + $4	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read / Write	PSR	WL		DC					PM							
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ISSI

ISSI Receive Control Register (SRXCR)

Bits	Name	Description
15	PSR	**Prescaler Range**
		0 Fixed prescaler if bypassed
		1 Fixed divide-by-eight prescaler is operational
14 - 13	WL	**Word Length Control**
		Used to select the length of the data words. See the following table.

WL1	WL0	Number of Bits/Word
0	0	8
0	1	10
1	0	12
1	1	16

12 - 8	DC	**Frame Rate Divider Control**
		Control the divide ratio for programmable frame rate dividers. The divide ratio ranges from 1 to 32 in Normal mode and from 2 to 32 in Network mode.
7 - 0	PM	**Prescaler Modulus Select**
		Specify the divide ratio of the prescale divider in the SSI clock generator. A divide ratio from 1 to 256 (PM[7:0]=$00 to $FF) can be selected.

ISSI Receive Control Register (SRXCR) $1FFE20 + $5	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	PSR	WL		DC					PM							
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ISSI

ISSI Control/Status Register (SCSR)

Bits	Name	Description	
15	DIV4DIS	**Divider 4 Disable**	
		0	FIX_CLK is equal to the IP_CLK/4
		1	FIX_CLK is equal to the IP_CLK
14	RSHFD	**Receive Shift Direction**	
		0	Data received MSB first
		1	Data received LSB first
13	RSCKP	**Receive Clock Polarity**	
		0	Falling edge of the CLK is used to capture data
		1	Rising edge of the CLK is used to capture the data
10	RFSI	**Receive Frame Sync Invert**	
		0	Receive frame sync is active high
		1	Receive frame sync is active low
9	RFSL	**Receive Frame Sync Length**	
		0	One-word long frame sync is selected
		1	One clock-bit long frame sync is selected
8	REFS	**Receive Early Frame Sync**	
		0	Frame sync intiated as first bit of received data
		1	Frame sync initiated one bit prior to received data
7	RDR	**Receive Data Ready Flag**	
		0	—
		1	ISSI Receive Data (SRX) register or Receive FIFO loaded with a new value

ISSI Control/Status Register (SCSR) $1FFE20 + $2	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	DIV4DIS	RSHFD	RSCKP	0	0	RFSI	RFSL	REFS	RDR	TDE	ROE	TUE	TFS	RFS	RFF	TFE
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

See the following page for continuation of this register

ISSI

ISSI Control/Status Register (SCSR) continued

Bits	Name	Description	
6	TDE	**Transmit Data Register Empty**	
		0	Data written to the STX or the STSR
		1	No data waiting to be transferred to STX
5	ROE	**Receive Overrun Error**	
		0	Power-on, or ISSI reset, is also cleared by reading the SCSR with the ROE bit set, followed by reading the SRX register. Cleaning the RE bit does not affect the ROE bit.
		1	Set when the RXSR Register is filled and ready to transfer to the SRX of Receive FIFO register, these registers are already full.
4	TUE	**Transmitter Underrun Error**	
		0	This bit is cleared by power-on, or ISSI reset and is cleared by reading the SCSR with the TUE bit set followed by writing to the STX register or to the STSR.
		1	When TXSR is empty and a transmit time slot occurs
3	TFS	**Transmit Frame Sync**	
		0	During power-on, ISSI reset, or when starting transmission of next slot in Network mode
		1	Frame sync occurred during transmission of last word written to STX register
2	RFS	**Receive Frame Sync**	
		0	During power-on, ISSI reset, or next slot of frame begins to receive in Network mode
		1	Frame sync occurred during receiving the next word into SRX
1	RFF	**Receive FIFO Full**	
		0	Cleared by normal operation by reading the SRX register
		1	Data level in Receive FIFO reaches selected Receive FIFO Watermark (RFWM) threshold
0	TFE	**Transmit FIFO Empty**	
		0	Power-on resets when ISSI is disabled transmit FIFO has more than threshold values
		1	Set when transmit section is programmed with TXFIFO enabled and data level falls below the selected TXFIFO threshold

ISSI Control/Status Register (SCSR) $1FFE20 + $2	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	DIV4DIS	RSHFD	RSCKP	0	0	RFSI	RFSL	REFS	RDR	TDE	ROE	TUE	TFS	RFS	RFF	TFE
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

ISSI

ISSI Control/Status Register 2 (SCSR2)

Bits	Name	Description	
15	RIE	**Receive Interrupt Enable**	
		0	Disables the receive interrupt
		1	Allows interrupt of program controller if ROE or RFF/RDF bit is set
14	TIE	**Transmit Interrupt Enable**	
		0	Disables the transmit interrupt
		1	Allows interrupt of program controller in TUE or TFE/TDE bit is set
13	RE	**Receive Enable**	
		0	Receiver is disabled
		1	Receiver in enabled
12	TE	**Transmit Enable**	
		0	Transmitter is disabled
		1	Transmitter is enabled
11	RFEN	**Receive FIFO Enable**	
		0	Disables receive FIFO
		1	Enables receive FIFO
10	TFEN	**Transmit FIFO Enable**	
		0	Disables transmit FIFO
		1	Enable transmit FIFO
9	RXDIR	**Receive Clock Direction**	
		0	Clock source is external
		1	Clock is generated internally
8	TXDIR	**Transmit Clock Direction**	
		0	Clock source is external
		1	Clock is generated internally

ISSI Control/Status Register 2 (SCSR2) $1FFE20 + $3	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	RIE	TIE	RE	TE	RFEN	TFEN	RXDIR	TXDIR	SYN	TSHFD	TSCKP	SSIEN	NET	TFSI	TFSL	TEFS
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

See the following page for continuation of this register

ISSI

ISSI Control/Status Register 2 (SCSR2) continued

Bits	Name	Description	
7	SYN	**Synchronous Mode**	
		0	Asynchronous mode
		1	Synchronous mode
6	TSHFD	**Transmit Shift Direction**	
		0	MSB is transmitted first
		1	LSB is transmitted first
5	TSCKP	**Transmit Clock Polarity**	
		0	Rising edge of the bit clock is used to clock the data out
		1	Falling edge of the bit clock is used to clock the data out
4	ISSIEN	**ISSI Enable**	
		0	ISSI is disabled
		1	ISSI is enabled
3	NET	**Network Mode**	
		0	Normal mode of operation selected
		1	Network mode of operation selected
2	TFSI	**Transmit Frame Sync Invert**	
		0	Frame sync is active high
		1	Frame sync is active low
1	TFSL	**Transmit Frame Sync Length**	
		0	One word long frame sync is selected
		1	One clock-bit long frame sync is selected
0	TEFS	**Transmit Early Frame Sync**	
		0	Frame sync is intiated as the first bit of data is transmitted
		1	Frame sync is initiated one bit prior to the data being transmitted

ISSI Control/Status Register 2 (SCSR2) $1FFE20 + $3	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	RIE	TIE	RE	TE	RFEN	TFEN	RXDIR	TXDIR	SYN	TSHFD	TSCKP	SSIEN	NET	TFSI	TFSL	TEFS
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ISSI

ISSI Time-Slot Register (STSR)

Bits	Name	Description
15 - 0	STSR	**ISSI Time-Slot Register**
		Used when data is not to be transmitted in an available transmit time slot. The time-slot register is a *write-only* register. It behaves like an alternative transmit data register.

ISSI Time Slot Register (STSR) $1FFE20 + $6	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read																
	Write	DUMMY REGISTER, WRITTEN DURING INACTIVE TIME-SLOTS (NETWORK MODE)															
	Reset	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

denotes Reserved Bits

ISSI

ISSI FIFO Control/Status Register (SFCSR)

Bits	Name	Description	
15 - 12	RFCNT	**Receive FIFO Counter**	
		0000	0 Data words in RXFIFO
		0001	1 Data word in RXFIFO
		0010	2 Data words in RXFIFO
		0011	3 Data words in RXFIFO
		0100	4 Data words in RXFIFO
		0101	5 Data words in RXFIFO
		0110	6 Data words in RXFIFO
		0111	7 Data words in RXFIFO
		1000	8 Data words in RXFIFO
11 - 8	TFCNT	**Transmit FIFO Counter**	
		0000	0 Data words in TXFIFO
		0001	1 Data word in TXFIFO
		0010	2 Data words in TXFIFO
		0011	3 Data words in TXFIFO
		0100	4 Data words in TXFIFO
		0101	5 Data words in TXFIFO
		0110	6 Data words in TXFIFO
		0111	7 Data words in TXFIFO
		1000	8 Data words in TXFIFO

ISSI FIFO Control/Status Register (SFCSR) $1FFE20 + $7	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	RFCNT				TFCNT				RFWM				TFWM			
	Write																
	Reset	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

denotes Reserved Bits

See the following page for continuation of this register

ISSI

ISSI FIFO Control/Status Register (SFCSR) continued

7 - 4	RFWM	Receive FIFO Full Watermark
		This bit field controls the threshold setting of the transmit FIFO empty flag. (The table below provides this bit field's encoding)
		0000 Reserved
		0001 RFF set when at least 1 data word has been written to the RXFIFO. Set when RXFIFO = 1, 2, 3, 4, 5, 6, 7, or 8 data words
		0010 RFF set when 2 or more data word has been written to the RXFIFO. Set when RXFIFO = 2, 3, 4, 5, 6, 7, or 8 data words
		0011 RFF set when 3 or more data word has been written to the RXFIFO. Set when RXFIFO = 3, 4, 5, 6, 7, or 8 data words
		0100 RFF set when 4 or more data word has been written to the RXFIFO. Set when RXFIFO = 4, 5, 6, 7, or 8 data words
		0101 RFF set when 5 or more data word has been written to the RXFIFO. Set when RXFIFO = 5, 6, 7, or 8 data words
		0110 RFF set when 6 or more data word has been written to the RXFIFO. Set when RXFIFO = 6, 7, or 8 data words
		0111 RFF set when 7 or more data word has been written to the RXFIFO. Set when RXFIFO = 7, or 8 data words
		1000 RFF set when 8 data word has been written to the RXFIFO. Set when RXFIFO = 8 data words
3 - 0	TDWM	Transmit FIFO Empty Watermark
		This bit field controls the threshold where the Transmit FIFO Empty is set. (The table below provides this bit field's encoding)
		0000 Reserved
		0001 TFE set when there is 1 empty slot in TXFIFO. (Default) Transmit FIFO empty is set when TXFIFO = <7 data
		0010 TFE set when there is 2 or more empty slots in TXFIFO. Transmit FIFO empty is set when TXFIFO = <6 data
		0011 TFE set when there is 3 empty slot in TXFIFO. Transmit FIFO empty is set when TXFIFO = <5 data
		0100 TFE set when there is 4 empty slot in TXFIFO. Transmit FIFO empty is set when TXFIFO = <4 data
		0101 TFE set when there is 5 empty slot in TXFIFO. Transmit FIFO empty is set when TXFIFO = <3 data
		0110 TFE set when there is 6 empty slot in TXFIFO. Transmit FIFO empty is set when TXFIFO = <2 data
		0111 TFE set when there is 7 empty slot in TXFIFO. Transmit FIFO empty is set when TXFIFO = <1 data
		1000 TFE set when there is 8 empty slot in TXFIFO. Transmit FIFO empty is set when TXFIFO = <0 data

ISSI FIFO Control/Status Register (SFCSR) $1FFE20 + $7	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	RFCNT				TFCNT				RFWM				TFWM			
	Write																
	Reset	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

denotes Reserved Bits

ISSI

ISSI Option Register (SOR)

Bits	Name	Description
6	RFDIR	**Receive Frame Direction**
		This control bit selects the direction and source of the Receive Frame sync signal
5	TFDIR	**Transmit Frame Direction**
		This control bit selects the direction and source of the Transmit Frame sync signal

ISSI Option Register (SOR) $1FFE20 + $9	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	0	RFDIR	TFDIR	0	0	0	0	0
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

TMR

TMR Channel Control Register (CTL)

Bits	Name	Description	
15 - 13	CM	**Count Mode**	
		000	No operation
		001	Count rising edges of primary source.
		010	Count rising and falling edges of primary source.
		011	Count rising edges of primary source while secondary input is active high
		100	Quadrature Count mode uses primary and secondary sources
		101	Count primary source rising edges, secondary source specifies direction (1=minus)
		110	Edge of secondary source triggers primary count until compared
		111	Cascaded Counter mode (up/down)
12 - 9	PCS	**Primary Count Source**	
		0000	Counter 0 input pin
		0001	Counter 1 input pin
		0010	Counter 2 input pin
		0011	Counter 3 input pin
		0100	Counter 0 output
		0101	Counter 1 output
		0110	Counter 2 output
		0111	Counter 3 output
		1000	Prescaler (IPBus clock divide by 1)
		1001	Prescaler (IPBus clock divide by 2)
		1010	Prescaler (IPBus clock divide by 4)
		1011	Prescaler (IPBus clock divide by 8)
		1100	Prescaler (IPBus clock divide by 16)
		1101	Prescaler (IPBus clock divide by 32)
		1110	Prescaler (IPBus clock divide by 64)
		1111	Prescaler (IPBus clock divide by 128)

TMRA0_CTRL (Timer A, Channel 0 Control)—Address: TMRA_BASE + $6
TMRA1_CTRL (Timer A, Channel 1 Control)—Address: TMRA_BASE + $E
TMRA2_CTRL (Timer A, Channel 2 Control)—Address: TMRA_BASE + $16
TMRA3_CTRL (Timer A, Channel 3 Control)—Address: TMRA_BASE + $1E

TMR Control Register (CTL) $1FFE80 + $6, $E, $16, $1E	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	CM			PCS				SCS		ONCE	LENGTH	DIR	EXT INIT	OM (OFLAG)		
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

See the following page for continuation of this register

TMR

TMR Control Register (CTL) continued

Bits	Name	Description	
8 - 7	**SCS**	**Secondary Count Source**	
		This bit field provides additional information used for counting, such as direction.	
		00	Counter 0 input pin
		01	Counter 1 input pin
		10	Counter 2 input pin
		11	Counter 3 input pin
6	**CO**	**Count Once**	
		This bit selects continuous or one-shot counting mode.	
		0	Count repeatedly
		1	Count until compare, then stop. Counting up: compares when counter reaches CMP1 value. Counting down: compares when counter reaches CMP2 value.
5	**CL**	**Count Length**	
		Determines whether counter counts to the compare value, reinitializing itself.	
		0	Rollover
		1	Count until compare, then reinitialize

TMRA0_CTRL (Timer A, Channel 0 Control)—Address: TMRA_BASE + $6
TMRA1_CTRL (Timer A, Channel 1 Control)—Address: TMRA_BASE + $E
TMRA2_CTRL (Timer A, Channel 2 Control)—Address: TMRA_BASE + $16
TMRA3_CTRL (Timer A, Channel 3 Control)—Address: TMRA_BASE + $1E

TMR Control Register (CTL) $1FFE80 + $6, $E, $16, $1E	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	CM			PCS				SCS		ONCE	CL	DIR	EI	OM (OFLAG)		
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

See the following page for continuation of this register

TMR

TMR Control Register (CTL) continued

Bits	Name	Description	
4	DIR	**Direction**	
		Bit selects either normal count up direction, or count down direction.	
		0	Count up
		1	Count down
3	EXT INIT	**External Initialization**	
		0	External counter/timers cannot force a reinitialization of this counter/timer
		1	External counter/timers may force reinitialization of this counter/timer
2 - 0	OM	**Output Mode**	
		These bits determine the mode of operation.	
		000	Asserted while counter is active
		001	Clear OFLAG output on successful compare
		010	Set OFLAG output on successful compare
		011	Toggle OFLAG output on successful compare
		100	Toggle OFLAG output using alternating compare registers
		101	Set on compare, cleared on secondary source input edge
		110	Set on compare, cleared on counter roll over
		111	Enable Gated Clock output while counter is active

TMRA0_CTRL (Timer A, Channel 0 Control)—Address: TMRA_BASE + $6
TMRA1_CTRL (Timer A, Channel 1 Control)—Address: TMRA_BASE + $E
TMRA2_CTRL (Timer A, Channel 2 Control)—Address: TMRA_BASE + $16
TMRA3_CTRL (Timer A, Channel 3 Control)—Address: TMRA_BASE + $1E

TMR Control Register (CTL) $1FFE80 + $6, $E, $16, $1E	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	CM			PCS				SCS		ONCE	CL	DIR	EI	OM (OFLAG)		
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TMR

TMR Status and Control Register (SCR)

Bits	Name	Description
15	TCF	**Timer Compare Flag**
		This bit is set when a successful compare occurs. Cleared by writing a 0 to it.
14	TCFIE	**Timer Compare Flag Interrupt Enable**
		When set, this bit enables interrupts when the TCF bit is set.
13	TOF	**Timer Overflow Flag**
		Depending on count direction, bit is set when controller rolls over to maximum values of $FFFF or $0000
12	TOFIE	**Timer Overflow Flag Interrupt Enable**
		When set, this bit enables interrupts when the TOF bit is set.
11	IEF	**Input Edge Flag**
		This bit is set when a positive input transition occurs. Clear the bit by writing 0 to it.
10	IEFIE	**Input Edge Flag Interrupt Enable**
		When set, this bit enables interrupts when the IEF bit is set.
9	IPS	**Input Polarity Select**
		When set, this bit inverts the input signal polarity.
8	INPUT	**External Input Signal**
		This *read-only* bit reflects the current state of the external input pin.

TMRA0_SCR (Timer A, Channel 0 Status/Control)—Address: TMRA_BASE + $7
TMRA1_SCR (Timer A, Channel 1 Status/Control)—Address: TMRA_BASE + $F
TMRA2_SCR (Timer A, Channel 2 Status/Control)—Address: TMRA_BASE + $17
TMRA3_SCR (Timer A, Channel 3 Status/Control)—Address: TMRA_BASE + $1F

TMR Status and Control Register (SCR) $1FFE80 + $7, $F, $17, $1F	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	TCF	TCFIE	TOF	TOFIE	IEF	IEFIE	IPS	INPUT	CM		MSTR	EEOF	VAL	0	OPS	OEN
	Write														FORCE		
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

See the following page for continuation of this register

TMR

TMR Status/Control Register (SCR) continued

Bits	Name	Description
7 - 6	CAPTURE MODE	**Input Capture Mode**
		These bits specify the operation of the Capture register and the operation of the input edge flag.
		00 — Capture function is disabled
		01 — Load Capture register on rising edge of input
		10 — Load Capture register on falling edge of input
		11 — Load Capture register on any edge of input
5	MSTR	**Master Mode**
		When set, this bit enables Compare function's output to be broadcasted to the other counter/timers in the module.
4	EEOF	**Enable External OFLAG Force**
		When set, this bit enables the compare from another counter/timer within the same module to force the state of this counter's OFLAG output signal.
3	VAL	**Forced OFLAG Value**
		This bit determines the value of the OFLAG output signal when a software triggered FORCE command, or another counter/timer set as a master, issues a FORCE command.
2	FORCE	**Force OFLAG Output**
		This *write-only* bit forces the current value of the VAL bit to be written to the OFLAG output. This bit is read as 0. The VAL and FORCE bits can be written simultaneously in a single write operation. Write to the FORCE bit only when the counter is disabled.
1	OPS	**Output Polarity Select**
		This bit determines the polarity of the OFLAG output signal.
		0 — True polarity
		1 — Inverted polarity
0	OEN	**Output Enable**
		When set, this bit enables the OFLAG output signal to be placed on the external pin. Setting this bit connects a timer's output pin to its input.

TMRA0_SCR (Timer A, Channel 0 Status/Control)—Address: TMRA_BASE + $7
TMRA1_SCR (Timer A, Channel 1 Status/Control)—Address: TMRA_BASE + $F
TMRA2_SCR (Timer A, Channel 2 Status/Control)—Address: TMRA_BASE + $17
TMRA3_SCR (Timer A, Channel 3 Status/Control)—Address: TMRA_BASE + $1F

TMR Status and Control Register (SCR) $1FFE80 + $7, $F, $17, $1F	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	TCF	TCFIE	TOF	TOFIE	IEF	IEFIE	IPS	INPUT	CM		MSTR	EEOF	VAL	0	OPS	OEN
	Write														FORCE		
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

TMR

TMR Compare Register 1 (CMP1)

Bits	Name	Description
15 - 0	COMPARISON1	Timer Compare 1
		This read/write register stores the value used for comparison with counter value.

TMRA0_CMP1 (Timer A, Channel 0 Compare 1)—Address: TMRA_BASE + $0
TMRA1_CMP1 (Timer A, Channel 1 Compare 1)—Address: TMRA_BASE + $8
TMRA2_CMP1 (Timer A, Channel 2 Compare 1)—Address: TMRA_BASE + $10
TMRA3_CMP1 (Timer A, Channel 3 Compare 1)—Address: TMRA_BASE + $18

TMR Compare Register1 (CMP1) $1FFE80 + $0, $8, $10, $18	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	COMPARISON VALUE 1															
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TMR

TMR Compare Register 2 (CMP2)

Bits	Name	Description
15 - 0	COMPARISON2	Timer Compare 2
		This read/write register stores the value used for comparison with counter value.

TMRA0_CMP2 (Timer A, Channel 0 Compare 2)—Address: TMRA_BASE + $1
TMRA1_CMP2 (Timer A, Channel 1 Compare 2)—Address: TMRA_BASE + $9
TMRA2_CMP2 (Timer A, Channel 2 Compare 2)—Address: TMRA_BASE + $11
TMRA3_CMP2 (Timer A, Channel 3 Compare 2)—Address: TMRA_BASE + $19

TMR Compare Register2 (CMP2) $1FFE80 +$1, $9 $11, $19	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	COMPARISON VALUE 2															
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TMR

TMR Capture Register (CAP)

Bits	Name	Description
15 - 0	CAPTURE	**Timer Capture**
		This read/write register stores the value captured from the counter.

TMRA0_CAP (Timer A, Channel 0 Capture)—Address: TMRA_BASE + $2
TMRA1_CAP (Timer A, Channel 1 Capture)—Address: TMRA_BASE + $A
TMRA2_CAP (Timer A, Channel 2 Capture—Address: TMRA_BASE + $12
TMRA3_CAP (Timer A, Channel 3 Capture)—Address: TMRA_BASE + $1A

TMR Capture Register (CAP) $1FFE80 + $2, $A $12, $1A	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	CAPTURE VALUE															
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TMR

TMR Load Register (LOAD)

Bits	Name	Description
15 - 0	LOAD	Timer Load
		This read/write register stores the value used to load the counter

TMRA0_LOAD (Timer A, Channel 0 Load)—Address: TMRA_BASE + $3
TMRA1_LOAD (Timer A, Channel 1 Load)—Address: TMRA_BASE + $B
TMRA2_LOAD (Timer A, Channel 2 Load)—Address: TMRA_BASE + $13
TMRA3_LOAD (Timer A, Channel 3 Load)—Address: TMRA_BASE + $1B

TMR Load Register (LOAD) $1FFE80 + $3, $B $13, $1B	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	LOAD VALUE															
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TMR

TMR Hold Register (HOLD)

Bits	Name	Description
15 - 0	HOLD	**Timer Hold**
		This read/write register stores the channel's value whenever any counter is read.

TMRA0_HOLD (Timer A, Channel 0 Hold)—Address: TMRA_BASE + $4
TMRA1_HOLD (Timer A, Channel 1 Hold)—Address: TMRA_BASE + $C
TMRA2_HOLD (Timer A, Channel 2 Hold)—Address: TMRA_BASE + $14
TMRA3_HOLD (Timer A, Channel 3 Hold)—Address: TMRA_BASE + $1C

TMR Hold Register (HOLD) $1FFE80 + $4, $C $14, $1C	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	HOLD VALUE															
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TMR

TMR Counter Register (CNTR)

Bits	Name	Description
15 - 0	COUNTER	Timer Counter
		This read/write register is the counter.

TMRA0_CNTR (Timer A, Channel 0 Counter)—Address: TMRA_BASE + $5
TMRA1_CNTR (Timer A, Channel 1 Counter)—Address: TMRA_BASE + $D
TMRA2_CNTR (Timer A, Channel 2 Counter)—Address: TMRA_BASE + $15
TMRA3_CNTR (Timer A, Channel 3 Counter)—Address: TMRA_BASE + $1D

TMR Counter Register (CNTR) $1FFE80 + $5, $D $15, $1D	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	COUNTER															
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

GPIO

GPIO Port A Peripheral Enable Register (GPIOA_PER)

Bits	Name	Description	
2 - 0	PE	**Port A Peripheral Enable**	
		0	GPIO mode; pin operation is controlled by GPIO registers
		1	Normal mode; pin operation is controlled by the EMI module

Peripheral Enable Register (GPIOA_PER) $1FFE60 + $0	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	1	1	1	1	1	1	1	1	1	1	1	1	1	PE		
	Write																
	Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

denotes Reserved Bits

GPIO

GPIO Port C Peripheral Enable Register (GPIOC_PER)

Bits	Name	Description	
5 - 0	PE	**Port C Peripheral Enable**	
		0	GPIO mode; pin operation is controlled by GPIO registers
		1	Normal mode; pin operation is controlled by the SPI and SSI modules

Peripheral Enable Register (GPIOC_PER) $1FFE68 + $8	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	1	1	1	1	1	1	1	1	1	1	PE					
	Write																
	Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

denotes Reserved Bits

GPIO

GPIO Port E Peripheral Enable Register (GPIOE_PER)

Bits	Name	Description	
1 - 0	PE	**Port E Peripheral Enable Register**	
		0	GPIO mode; pin operation is controlled by GPIO registers
		1	Normal mode; pin operation is controlled by the SCI module

Peripheral Enable Register (GPIOE_PER) $1FFE70 + $16	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	1	1	1	1	1	1	1	1	1	1	1	1	1	1	PE	
	Write																
	Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

denotes Reserved Bits

GPIO

GPIO Port A Data Direction Register (GPIOA_DDR)

Bits	Name	Description	
2 - 0	DD	**Port A Data Direction**	
		These bits control the pins' direction when in GPIO mode. In the Normal mode, these bits have no effect on the output enables or pull-up enables.	
		0	Pin is an output; pull-ups are dependent on value of PUE registers. (default)
		1	Pin is an output; pull-ups are disabled

Data Direction Register (GPIOA_DDR) $1FFE60 + $1	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	0	0	0	0	0	DD		
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

GPIO

GPIO Port C Data Direction Register (GPIOC_DDR)

Bits	Name	Description	
5 - 0	**DD**	**Port C Data Direction**	
		These bits control the pins' direction when in GPIO mode. In the Normal mode, these bits have no effect on the output enables or pull-up enables.	
		0	Pin is an output; pull-ups are dependent on value of PUE registers. (default)
		1	Pin is an output; pull-ups are disabled

Data Direction Register (GPIOC_DDR) $1FFE68 + $9	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	0	0	DD					
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

GPIO

GPIO Port E Data Direction Register (GPIOE_DDR)

Bits	Name	Description	
1 - 0	DD	**Port E Data Direction**	
		These bits control the pins' direction when in GPIO mode. In the Normal mode, these bits have no effect on the output enables or pull-up enables.	
		0	Pin is an output; pull-ups are dependent on value of PUE registers. (default)
		1	Pin is an output; pull-ups are disabled

Data Direction Register (GPIOE_DDR) $1FFE70 + $17	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	0	0	0	0	0	0	DD	
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

GPIO

GPIO Port A Data Register (GPIOA_DR)

Bits	Name	Description
2 - 0	DATA	**Port A Data**
		These bits control the output data while in the GPIO mode.

Data Register (GPIOA_DR) $1FFE60 + $2	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	0	0	0	0	0	DATA		
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

GPIO

GPIO Port C Data Register (GPIOC_DR)

Bits	Name	Description
5 - 0	DATA	**Port C Data**
		These bits control the output data while in the GPIO mode.

Data Register (GPIOC_DR) $1FFE68 + $A	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	0	0	DATA					
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

GPIO

GPIO Port E Data Register (GPIOE_DR)

Bits	Name	Description
1 - 0	DATA	**Port E Data**
		These bits control the output data while in the GPIO mode.

Data Register (GPIOE_DR) $1FFE70 + $18	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	0	0	0	0	0	0	0	0	0	0	0	0	0	0	DATA	
	Write																
	Reset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

denotes Reserved Bits

GPIO

GPIO Port A Pull-Up Enable Register (GPIOA_PUE)

Bits	Name	Description	
2 - 0	PE	**Port E Pull-Up Enable**	
		These bits control whether pull-ups are enabled for inputs in either Normal or GPIO mode.	
		0	Pull-ups disabled for inputs
		1	Pull-ups enabled for inputs (default)

Pull-Up Enable Register (GPIOA_PUE) $1FFE60 + $3	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	1	1	1	1	1	1	1	1	1	1	1	1	1	PE		
	Write																
	Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

denotes Reserved Bits

GPIO

GPIO Port C Pull-Up Enable Register (GPIOC_PUE)

Bits	Name	Description	
5 - 0	PE	**Port C Pull-Up Enable**	
		These bits control whether pull-ups are enabled for inputs in either Normal or GPIO mode.	
		0	Pull-ups disabled for inputs
		1	Pull-ups enabled for inputs (default)

Pull-Up Enable Register (GPIOC_PUE) $1FFE68 + $B	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	1	1	1	1	1	1	1	1	1	1	PE					
	Write																
	Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

denotes Reserved Bits

GPIO

GPIO Port E Pull-Up Enable Register (GPIOE_PUE)

Bits	Name	Description	
1 - 0	PE	**Port E Pull-up Enable**	
		These bits control whether pull-ups are enabled for inputs in either Normal or GPIO mode.	
		0	Pull-ups disabled for inputs
		1	Pull-ups enabled for inputs (default)

Pull-Up Enable Register (GPIOE_PUE) $1FFE70 + $19	Bits	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	Read	1	1	1	1	1	1	1	1	1	1	1	1	1	1	PE	
	Write																
	Reset	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

denotes Reserved Bits

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How to Reach Us:

Home Page:
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USA/Europe or Locations Not Listed:
Freescale Semiconductor
Technical Information Center, CH370
1300 N. Alma School Road
Chandler, Arizona 85224
+1-800-521-6274 or +1-480-768-2130
support@freescale.com

Europe, Middle East, and Africa:
Freescale Halbleiter Deutschland GmbH
Technical Information Center
Schatzbogen 7
81829 Muenchen, Germany
+44 1296 380 456 (English)
+46 8 52200080 (English)
+49 89 92103 559 (German)
+33 1 69 35 48 48 (French)
support@freescale.com

Japan:
Freescale Semiconductor Japan Ltd.
Headquarters
ARCO Tower 15F
1-8-1, Shimo-Meguro, Meguro-ku,
Tokyo 153-0064, Japan
0120 191014 or +81 3 5437 9125
support.japan@freescale.com

Asia/Pacific:
Freescale Semiconductor Hong Kong Ltd.
Technical Information Center
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DSP56852UM
Rev. 4
6/2005